



# Africa Research in Sustainable Intensification for the Next Generation - West Africa

Research in sustainable intensification of cereal-based farming systems in the Guinea-Sudan-Savanna of West Africa

## 2014-2016 Work plans

Produced by:

Asamoah Larbi, Bekele Kuto, Irmgard Hoeschle-Zeledon, IITA (International Institute of Tropical Agriculture); Birhanu Zemadim, Eva Weltzien, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics); Joachim Binam, Catherine Dembele, Anehmbom Mundi, ICRAF (International Center for Agroforestry Research); Augustine Ayantunde, ILRI (International Livestock Research Institute); Abdou Tenkouano, AVRDC (The World Vegetable Center); Bougouna Sogoba, AMEDD (Association Malienne d'Eveil et de Developpement Durable); Saaka Buah, SARI (Savanna Agricultural Research Institute); Mahama Saaka, Herbert Dei, UDS (University for Development Studies); Daniel Boye Okine, KNUST (Kwame Nkrumah University of Science and Technology)

Published by:

International Institute of Tropical Agriculture (IITA)

May 2014

[www.africa-rising.net](http://www.africa-rising.net)



The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-for-development projects supported by the United States Agency for International Development as part of the U.S. government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment. <http://africa-rising.net/>



This document is licensed for use under a Creative Commons Attribution-Noncommercial-Share Alike 3.0 Unported License

This document was made possible with support from the American people delivered through the United States Agency for International Development (USAID) as part of the US Government's Feed the Future Initiative. The contents are the responsibility of the producing organization and do not necessarily reflect the opinion of USAID or the U.S. Government.

<b>Contents</b>	<b>i</b>
<b>Partners</b>	<b>ii</b>
<b>Summary</b>	<b>1</b>
<b>1 Introduction</b>	<b>1</b>
<b>1.1 Africa RISING in West Africa</b>	<b>1</b>
1.1.1 Implementation strategy	3
1.1.2 Scale of operation	3
1.1.3 Knowledge transfer strategies	3
1.1.4 Research hypotheses	
<b>2 Planned work – description of work-packages (WP)</b>	<b>5</b>
<b>2.1 Situation Analysis (Research Output 1)</b>	<b>5</b>
WP-1. Socio-economic studies on sustainable intensification in northern Ghana and southern Mali	5
<b>2.2 Integrated Systems Improvement (Research Output 2)</b>	<b>11</b>
WP-2. Raising and sustaining productivity in cereal-legume cropping systems in northern Ghana	11
WP-3. Biological control of aflatoxins in maize with Aflasafe Ghanaian product GH01	20
WP-4. Integrating vegetables into cereal-legume cropping systems in northern Ghana	24
WP-5. Improving farm and field productivity and profitability in southern Mali	30
WP-6. Intensifying livestock and poultry production in northern Ghana and southern Mali	36
WP-7. Raising and sustaining productivity in crop-livestock systems in northern Ghana	42
WP-8. Land, soil and water management to intensify cereal-legume farming systems in Ghana	50
WP-9. Managing natural resources to increase watershed productivity in southern Mali	60
WP-10. Improving household nutrition and value addition in northern Ghana and southern Mali	67
<b>3 Consolidated Budget for WA 2014</b>	<b>73</b>

## Partners

AMASSA	Afrique Verte, Mali
AMEDD	Association Malienne d’Eveil et de Developpement Durable, Mali
ARI	Animal Research Institute, Ghana
AVRDC	The World Vegetable Center
CBOs	Community-based Organizations, Ghana
CIAT	International Center for Tropical Agriculture
CMDT	Compagnie Malienne de Developpement des Textiles, Mali
CRI	Crops Research Institute, Ghana
FRI	Food Research Institute, Ghana
GLDB	Grains and Legumes Development Board, Ghana
GUIFFA	Guinea Fowl Farmers Association, Ghana
HI	Heifer International
ICRAF	World Agroforestry Center
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IER	Institut d’Economie Rurale, Mali
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INSTI	Institute for Scientific and Technological Information, Ghana
IWMI	International Water Management Institute
KNUST	Kwame Nkrumah University of Science and Technology, Ghana
MOBIOM	Mouvement Biologique du Mali, Mali
MoFA	Ministry of Food and Agriculture, Ghana
MoH	Ministry of Health, Ghana
NORGFA	Northern Region Guinea Fowl Farmers Association, Ghana
PRA	Presbyterian Agricultural Services, Ghana
SARI	Savanna Agricultural Research Institute, Ghana
SEEDPAG	Seed Producers Association of Ghana
SNV	Netherlands Development Organization, Ghana
SRI	Soil Research Institute, Ghana
UDS	University for Development Studies, Ghana
UG	University of Ghana, Ghana
WIENCO	Wienco Seed Company, Ghana
WUR	Wageningen University and Research Center, The Netherlands
WIAD	Women in Agriculture Development, Ghana
WRI	Water Resources Institute, Ghana

## Summary

The Africa RISING West Africa project (AR-WA) is being implemented by multi-disciplinary research teams and development partners from the public and private sectors in collaboration with farmers and community-based organizations (CBOs) at intervention communities in northern Ghana and southern Mali. The work plan presented here consists of 10 work-packages (WP), covering Research Output 1 (Situation Analysis – WP-1) and Research Output 2 (Integrated Systems Improvement – WP-2 to 10) of the Africa RISING Framework. It does not cover research on Scaling-up and Delivery Systems (Research Output 3) per se, but various delivery approaches will be used to exchange knowledge and disseminate technologies in WP 2-10. The work-packages are: WP-1: Socio-economic studies on sustainable intensification in northern Ghana and southern Mali; WP-2: Raising and sustaining productivity in cereal-legume cropping systems in northern Ghana; WP-3: Biological control of aflatoxins in maize with Aflasafe Ghanaian product GH01; WP-4: Integrating vegetables into cereal-legume cropping systems in northern Ghana; WP-5: Improving farm and field productivity and profitability in northern Ghana; WP-6: Intensifying livestock and poultry production in northern Ghana and southern Mali; WP-7: Raising and sustaining productivity in crop-livestock systems in northern Ghana; WP-8: Land, soil and water management to intensify cereal-legume farming systems in Ghana; WP-9: Managing natural resources to increase watershed productivity in southern Mali; and WP-10: Improving household nutrition and value addition in northern Ghana and southern Mali. Planned activity for the research output on scaling and delivery will focus on comparison of delivery approaches used in both countries. A series of cross-cutting activities are planned. Key amongst them is: building the capacity of young female and male scientists for data management and analysis and integrated crop-livestock production.

## 1 Introduction

### 1.1 Africa RISING in West Africa

Africa RISING is being implemented in 25 intervention communities in the three northern regions of Ghana (Fig. 1), and 10 villages in the Bougouni-Yanfolila and Koutiala districts of the Sikasso Region in southern Mali (Fig. 2). It is intended to result in spillover effects to other similar agro-ecological zones.

The farming systems in the region are dominated by small-scale, resource-poor farmers whose livelihoods depend on rain-fed crop, livestock, and crop–livestock farming systems. Main staple crops are cereals (maize, rice, sorghum, pearl millet), legumes (groundnut, cowpea, soybean, Bambara nut, pigeon pea), and vegetables (roselle, okra, pepper onion, garden egg, tomato, amaranths, pumpkin). The cereals are either grown in pure stands or intercropped/rotated with the legumes and a variety of vegetables.

Crop yields on farmers' fields are generally poor due to low and variable rainfall, drought, low and declining soil fertility, use of low yielding varieties, lack of quality seed of improved crop varieties and land preparation equipment, high cost of inputs and postharvest losses, labour constraints that lead to poor growing conditions (late sowing, sub-optimal plant populations, inadequate control of weeds, *Striga*, pests and diseases), and low use of organic or mineral fertilizers.

Cattle, sheep, goats, pigs, chicken, guinea fowl, turkeys, and ducks are reared for meat, milk, egg, land preparation, transport, manure, and cash. The animals are mostly managed under extensive and semi-intensive systems with limited feed, shelter, health care, and breeding management. Productivity of the animals is low due to inappropriate husbandry (feeding, health care, housing, and breeding) practices that result in high mortality rates. Farmers have limited access to veterinary services, and improved livestock breeds. In general, the crop and livestock enterprises are weakly integrated.

Diets of most rural poor farm-families are often dominated by the intake of basic staple foods (e.g., maize, rice, millet, and sorghum) which are usually deficient in micronutrients such as vitamin A, iron, and zinc needed to prevent malnutrition. The nutritional status of most farm households, especially pregnant women, breastfeeding mothers, and children below 24 months of age, is therefore poor. Chronic malnutrition is common and linked to low income, unsuitable food processing and feeding practices, and iron deficiency.

Farmers have limited access to input and output markets. Enabling institutions and policies are also lacking. Due to inadequacies of traditional promotional and scaling-up/out pathways, there is a large, unmet demand

for information and technology, especially by women. This has led to low adoption of improved technologies and best practices by farmers to reduce food insecurity, poverty, and natural resource degradation.

The activities presented in this work plan were selected to address the above challenges in the smallholder 'integrated cereal-legume-vegetable-livestock' farming systems in northern Ghana and southern Mali outlined above. The activities also address the expected outputs of the Africa RISING program, namely: increase productivity (WP-2, 3, 4, 5, 6, 7), conserve the natural resource base (WP-7, 8, 9), improve household nutrition (WP 10) and link farmers to markets (WP-1). Activities are linked within and across work-packages to ensure integration.

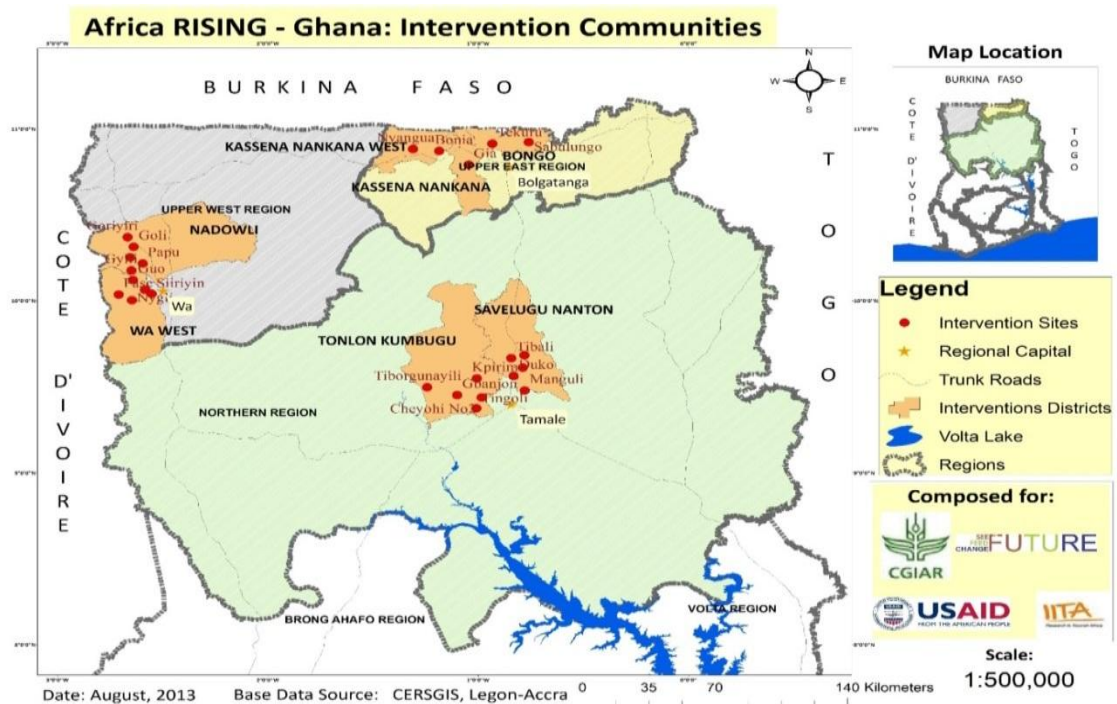


Figure 1. Africa RISING intervention communities in Ghana.



Figure 2. Africa RISING intervention villages in Mali.

### **1.1.1 Implementation strategy**

For participatory identification and implementation of activities to address the bio-physical and socio-economic constraints of the farming systems, community-based research-for-development (R4D) platforms which are merged to form district level platforms are promoted. The R4D Platforms consist of multi-disciplinary and multi-institutional research teams and development partners, male and women farmers, community-based organizations (CBOs), processors, service providers, traders, agro-input dealers, seed producers, public and private organizations and policy makers. Such approach facilitates farmer experimentation and evaluation, and ensures ownership by stakeholders, sustainability, and effective scaling-out and scaling-up of introduced technologies. Strategic partnerships are built with existing initiatives and farmer associations, non-governmental organizations (NGOs) and international organizations working on food security, poverty, household nutrition and environmental issues.

The activities are implemented mostly on-farm and on-station. The on-farm activities are managed by researchers, researchers and farmers, and farmers only. In addition to comparing intensified practices with farmers' practices, the on-farm activities are used to demonstrate new technologies and/or a combination of technologies through farmers' field days, farmers' field schools and exchange visits. They are also used to train farmers, extension and research assistants. The on-station activities are mostly used by graduate students as part of their dissertation research to test and/or develop new technologies.

Strengthening human capacity at all levels from farmers and their associations' officers, development workers, field and laboratory technicians, scientists and policy makers is a key component of the project. Academic training at the MSc and PhD level focuses on research to address important knowledge gaps, and to develop 'second generation' technologies that may be suited specifically to particular recommendation domains.

Gender awareness and gender equity, youth and under-privileged groups within society are considered in all project activities. Barriers-to-participation are reduced by offering gender sensitive interventions. Women interest groups (WIGs) are promoted to ensure effective participation of women.

### **1.1.2 Scale of operation**

The scale of implementation varies with activity in each country. It ranges from the plot to farm/field scale or from household to the community level.

Most of the activities are implemented at the plot or field levels. Nevertheless, results and outputs from the activities can be extrapolated to larger scales and bigger recommendation domains using modeling, Geographical Information Systems (GIS) and Remote Sensing techniques. For example, our preliminary GIS analysis showed that results from plot activities implemented at the Natodori intervention community in the Upper West Region of Ghana can be applied to other West African countries with similar agro-ecology and socio-economic environment.

### **1.1.3 Knowledge transfer strategies**

- Establish research-for-development plots to demonstrate technology being tested.
- Participatory and joint learning approaches for technology testing, e.g., 'mother-baby' approach
- Offer training courses for different stakeholders (research and extension staff, NGO staff, farmers)
- On-the job training of local staff and farmers
- Publish interim and annual reports
- Publish proceedings and journal papers
- Develop media materials (posters, policy briefs, leaflets, films) for farmers, extension staff, etc.
- Organize exchange visits for farmers, research and extension staff.

### **1.1.4 Research hypotheses**

The project contributes to the overall program research and development outputs. The key project hypotheses which will contribute to testing of the program hypotheses on adoption, integration and trade-off are:

1. A combination of improved crop varieties and agronomic practices will result in higher food/feed yields, income and household food security than single technologies. (WP-2: Activities 2,3,4,5,7,8)

2. Combinations of improved livestock breeds and management practices will result in higher animal productivity, income, and household food security than single technologies. (WP-6: Activities 1, 2, 3; WP-7: Activity 6)
3. Integration of shrubs, trees, vegetables and water management practices into cereal-legume-livestock farming systems will increase food and feed outputs, improve human and livestock nutrition, increase household income and improve soil fertility. (WP-5: Activity 3; WP-7: Activity2)
4. Improved farm productivity reduces pressure on common lands, leading to reduced land degradation and forest clearing. (WP-9: Activity 4; WP-7: Activity 1)
5. Labor, profit, food security, and environmental trade-offs associated with farm diversification are minimized by targeting interventions to specific field and farm types. (WP-7: Activities 3, 4; WP-9: Activity 4)
6. Linking nutrition knowledge to agricultural innovations leads to improvements in nutrition and more diverse integrated farming systems. (WP-10: Activities 2, 3, 4, 5, 6)
7. Participatory testing and evaluation of farming system innovations targeted to gender and farm types will increase farmer experimentation, understanding of trade-offs, and adoption of technologies. (WP-7: Activities 3, 4; WP-8: Activities 1, 2, 3; WP-9: Activity 4)
8. Building social cohesion and local institutions for improved community land, water and grazing management will lead to reduced land degradation, forest clearing, and conflict over natural resource use. (WP-1: Activities 1, 2; WP-7: Activity 1; WP-8: Activities 6; WP-9: Activities 2, 3)



## 2 Planned work – description of work packages

### 2.1 Situation Analysis (Research Output 1)

#### *Work-package WP-1*

#### 1. Title: Socio-economic studies on sustainable intensification in the West African Guinea and Sudan Savanna

#### 2. Research team

Country	Name	Institution	Degree	Research interest	Role
Mali	Bekele Kotu	IITA	PhD	Agricultural economics	Coordinator
	Joachim Binam	ICRAF	PhD	Policy	Principal Investigator (PI)
	Bougouna Sogoba	AMEDD	MSc	Rural development	Deputy PI
	Birhanu Zemadim	ICRISAT	PhD	Land/Water management	Coordination
	Abdoulaye Diakite	MOBIOM	MSc	Training	Monitor meetings
	Anehmbom Mundi	ICRAF	MSc	Post harvest, nutrition	Nutrition
	Eva Weltzien	ICRISAT	PhD	Sorghum breeding	Coordination
	Gatien Falconnier	ICRISAT	MSc	Farming systems	Managing trial
	Catherine Dembele	ICRAF	PhD	Agroforestry	Managing trials
	Ousmane Sanogo	IER	PhD	Farming systems	Markets
	Katrien	WUR	PhD	Farming systems	Farming systems
	Descheemaeker				
Ghana	Mary Ollenburger	WUR	MSc	Farming systems	Managing trials
	John Bidzakin	SARI	MSc	Agricultural economics	Economic evaluation
	Asamoah Larbi	IITA	PhD	Crop-livestock systems	Coordination
	Richard Yeboah	UDS	PhD	Agricultural business	Agricultural business
	Shaibu Mellon	IITA	BSc	Agricultural economics	Market and agricultural business
	James Fearon	UDS	PhD	Agricultural economics	Field supervision and research

#### 3. Summary

This work-package provides socio-economic support to the other work-packages. It aims at facilitating the establishment of district level research-for-development platforms that recognize the multifaceted challenges of rural development and invites knowledge and actions of all stakeholders in the agricultural system in Ghana and Mali. This will be done by promoting the establishment of physical forums to facilitate interactions, and knowledge sharing among stakeholders selected from a commodity and a system value chain; leading to participatory diagnosis of challenges, joint exploration of opportunities and investigation of solutions. Key livestock value chains will be characterized, and feed markets surveyed. Cost-benefit analysis of promising interventions will be conducted and farmers linked to markets.

#### 4. Research problem and justification

Barriers to agricultural development are not only technological but also institutional (e.g., laws, regulations, attitudes, habits, practices, norms, values, culture, and incentives). Thus, many researchers and project managers in the field of agricultural development are currently confronted with studying, using and facilitation and/or implementing research-for-development platforms (R4DP), which entails a shift away from traditional linear research-extension-farmer transfer of technology towards agricultural innovation systems. The R4DP support the implementation of research and development; contribute to improving the relevance and impact of research; stimulate and strengthen interaction between multiple stakeholders; link different stakeholders to achieve a common objective; contribute to jointly identifying and solving complex problems; provide an enabling environment for innovation, and contribute to overcoming institutional barriers and creating institutional change. Development of R4DPs at the district level is key to successful implementation of the project and adoption of improved technologies.

Market access has been cited as the main reason slowing adoption of several agricultural technologies in northern Ghana and southern Mali. Markets for most agricultural produce are not developed as there are no permanent channels for commodity trade. Institutions seem to be unofficial and policies not well developed to meet the current challenges of markets. Improvement in market access will help smallholder farmers to source for quality inputs at reasonable prices, and also allow them to sell their inputs at profitable prices. The development and promotion of markets, and enabling institutions and policies will enhance the benefits of intensification, reduce poverty and create employment. Adoption and diffusion of intensification, which this

project seeks to achieve, will depend on a good and ready market for the produce. There is need to conduct research that helps farmers take better advantage of existing market opportunities and/or creating new ones.

## 5. Objectives

- 1 Mobilize communities, revise list of beneficiaries and geo-reference participating households
- 2 Establish and inaugurate at least 5 district level research-for-development platforms in Ghana and Mali
- 3 Conduct a stakeholder analysis to analyze existing stakeholders and their interest
- 4 Analyze value chains identified by the R4D platforms at the district levels
- 5 Assess cost and benefit of interventions
- 6 Link farmers to markets and input dealers
- 7 Create linkages, integration and synergies between work packages to identify options for scaling
- 8 Create knowledge sharing and learning framework to facilitate stakeholder interaction
- 9 Strengthen capacity of stakeholders on innovation system approaches
- 10 Identify and validate different stakeholders and their potential roles in the R4D
- 11 Monitor seasonal dynamics of agricultural product prices and availability
- 12 Monitor and understand medium term (3 year) evolution of basic farm household characteristics

## 6. Work-plan and procedures

**Activity 1** Mobilize communities and establish R4D Platforms in Ghana

Lead Scientist(s) Bekele Kotu, Asamoah Larbi Institution: IITA

Partner(s) Abdulai Naindow, Hajia Musa, Baba Musa, Dominic Maalv, David Waawula, Adam Seidu Vassco, Alhaji Musbao, Shaibu Mellon, Brain Akakpo, Hamid Seidu, Dickson Desire

Location(s) Duko, Tibali, Botingli, Passe, Guo, Zanko, Samboligo, Nyangua, Bonia

### Procedures

*Sub-activity 1.1: Community mobilization and workshops on 2013 activities:* Community consultation initiated in 2013 will continue. Community workshops will be organized to document farmers' comments on the 2013 participatory trials. The 2013 list of interested farmers will be revised. Households will be tagged or geo-referenced for easy monitoring.

*Sub-activity 1.2: Establishment of research for development platforms:* Preparations (involvement and validation of stakeholder) for establishment of R4DPs started in 2013 at all the intervention communities with the formation of farmer-based organizations. Identification, interviews, validation and recruitment of stakeholders will continue at the district level in all the regions. The R4DPs in the six districts will be launched between July and September 2014.

**Activity 2** Establishment and characterization of R4D Platforms in Mali

Lead Scientists(s) Joachim Binam, Bougouna Sogoba Institution: ICRAF, AMEDD

Other Scientist(s) Clarisse Umutoni, Gatien Falconnier, Yah Diakite, Abdoulaye Diakite, Birhanu Zemadim, Clarisse Umutoni, Ousmane Sanogo, Albert Rouamba, Abdoulaye Diakite, Katrien Descheemaeker, Agathe Diamo, Anehmbom Mundi, Catherine Dembele, Mary Ollenburger, Eva Weltzien, Augustine Ayantunde

Location(s) Bougouni and Koutiala/Yanfolila districts

### Procedures

*Sub-activity 2.1: Characterization of R4D Platform sites (Bougouni and Koutiala/Yanfolila districts):* A quick biophysical and social characterization of the R4DP site and an inventory of all stakeholders working within the site will be undertaken. This will involve a one-day workshop with all identified stakeholders above to conduct a stakeholder analysis and collect information on existing forms of interaction amongst stakeholders as well as information on indicators that are likely to be influenced by the presence of R4DP.

*Sub-activity 2.2: Quick assessment of relevant stakeholders:* The main objective of this is to document all organizations, external and internal, that are working within the R4D Platform site. This information can be obtained from secondary sources such as the site selection reports for Bougouni and Koutiala (early 2013), key informant interviews and/or through field visits. At least the following groups and institutions need to be covered: farmers, farmer groups, farmer organizations, local government authorities, NARES, input suppliers, agro-dealer shops, NGOs, local institution governing access and use of natural resources, policy

and decision makers and other project implementing organizations.

*Sub-activity 2.3: Stakeholder analysis and mapping:* All the partners identified will be invited to a one day stakeholders' meeting to carry out stakeholder analysis, existing interactions of the stakeholders, the types and intensity of interactions, and to get stakeholders to analyse their innovation capacity. This will involve individuals from the represented organizations answering a set of questions in a questionnaire. These questions will be used to map the existing linkages and analyse the strength of the linkages using social network analysis and to make an assessment of different micro-scenarios that represent different elements of the interactions and innovation capacity such as knowledge sharing, and coordination of activities to triangulate the information. This short questionnaire can be administered during the stakeholder analysis workshop.

*Sub-activity 2.4: Multi-stakeholder national workshop for feedback on results of the different work packages:* A two-day workshop will be organized (in Bamako in March 2014 and Bougouni or Koutiala in November 2014) to present recent findings to partners and adjust plans accordingly to improve integration and synergies. The first day is reserved for presentations, while the second day will allow for adjusting plans, improving integration and identification of synergies. On the first day, the leader or deputy leader of each work package will present the general results; while one to three presentations per work package will allow for detailed information on results and lessons learnt. This will lead to four, short, work package presentations and between four to eight in-depth presentations with discussions. On the second day, opportunities and constraints arising from the presentations will be identified and work groups will be formed to articulate how these can be dealt with and how we can ensure synergies between activities within a given work package and between work packages.

*Sub-activity 2.5: Establish and assess impact of R4D Platforms on technology adoption:* Methodological and capacity building workshops on R4D Platforms and kick-off meetings will be organized. The implementation process will be reviewed and lessons learnt documented. Participatory approaches will be used to monitor and evaluate the activities of the R4D Platforms. Household surveys and focus group discussions will be conducted with the various R4D Platforms to assess the socio-economic impact of the R4D Platforms on technology adoption and market participation.

<b>Activity 3</b>	Survey of feed markets and analysis of livestock value chains in Ghana	
Lead Scientist(s)	Augustine Ayantunde, Acho Okike	Institution: ILRI
Other Scientist(s)	Franklin Avornyo, Tunde Amole, Bekele Kotu	
Student(s)	Solomon Konlan, Emmanuel Gyakah, Joseph Clottey and Mohammed Shaibu	
Location(s)	Duko, Tibali, Botingli, Passe, Guo, Zanko, Samboligo, Nyangua	

### Procedures

*Sub-activity 3.1: Survey of livestock feed markets:* This activity is a continuation of the survey of feed markets in the 3 regions which started in the last quarter of 2013. It aims at understanding the market structure and opportunities for strengthening the fodder market value chains in a scenario of emerging feed market. Key feed value chain actors will be interviewed quarterly, that is the producers, buyers, and sellers. Information will be collected on price of different feed types in the project sites across seasons. Information on the price of the cereal (maize, rice, millet, sorghum) and legume (cowpea, groundnut) grains will also be collected in the project sites. At least 2 samples of every feed sold in the market(s) in or near the project sites / community will be collected per quarter for determination of nutritional quality. The feed samples collected will be air dried and processed for laboratory analysis for dry matter, ash content, nitrogen, fibre contents (Neutral Detergent Fibre, Acid Detergent Fibre, Lignin), dry matter digestibility and energy content. To establish price of the feeds sold in the markets per weight (kilogram) particularly for crop residues, feeds will be bought from the sellers, air dried and then weighed. The survey will be conducted every quarter. For the survey, between 10 and 20 feed value chain actors will be randomly selected and interviewed per project site. This feed market survey will be conducted at district markets in each region for one year.

*Sub-activity 3.2: Analysis of livestock value chains:* This activity will build on the study of promising livestock value chains conducted in 2013 in the 3 regions. The 3 value chains identified for the studies based on the community analysis of constraints and opportunities conducted last year are guinea fowls in the Northern region, small ruminants in Upper West and pigs in Upper East. Three MSc students have collected data on the identified value chains and the data entry and analysis are underway. In the present activity, validation

workshops will be organized to present the key results from the studies to the key value chain actors in each region. In addition, they will be trained in key aspects of value chain development.

<b>Activity 4</b>	Monitor market prices and characterize value chains in Mali	
Lead Scientists(s)	Ousmane Sanogo	Institution: IER
Other Scientist(s)	Katrien Descheemaeker	
Student (s)	Mary Ollenburger, Gatien Falconnier	
Location(s)	Koutiala and Bougouni/Yanfolila districts	

#### Procedures

*Sub-activity 4.1: Monthly monitoring of prices of agricultural products in three large, weekly markets in Koutiala and Bougouni:* An existing data collection protocol (developed in the McKnight project) for surveying agricultural inputs and outputs is shared with partners for comments and validation. With input from local partners, three major markets will be identified for the study in the Koutiala and Bougouni areas. The validated protocol is then used to survey and monitor market prices on a monthly basis for a period of two years. Data will be entered and presented in tabular form every 6 months and a synthesis of results and main conclusions are presented in a short report every year from the start of monitoring. This information is used whenever necessary (in the IP meetings, in the country meetings, during feedback sessions and cost-benefit analyses with farmers and for farm system analyses).

*Sub-activity 4.2: Annual monitoring of basic farming household characteristics in Africa RISING villages:* Annual monitoring and updating of basic household assets (animals, land allocated to different crops, equipment, household members and prices of agricultural commodities). The existing data collection protocol (developed in 2013) is amended, validated and used to collect data on an annual basis (March-April). Data is entered and shared with partners for their use (mainly for farm system analyses, may also be useful in discussions in innovation platforms/feedback, review and planning workshops at different levels).

*Sub-activity 4.3: Value chain studies on at least three value chains identified by the R4D platforms:* The R4D Platforms at the district level will identify promising value chains on which analyses will be performed. Analyses will be conducted by MSc. students (still to be identified), results shared and validated in district level and national level meetings.

<b>Activity 5</b>	Conduct cost benefit analysis of interventions and link farmers to markets in Ghana	
Lead Scientists(s)	Bekele Kuto	Institution: IITA
Other Scientist(s)	John Bidzakin, Richard Yeboah, Shaibu Mellon, James Fearon	
Location(s)	Duko, Tibali, Botingli, Passe, Guo, Zanko, Samboligo, Nyangua	

#### Procedures

*Sub-activity 5.1: Economic feasibility studies of agronomic studies:* Cost-benefit analysis of 2012 and 2013 agronomic studies will be conducted. Input, output and labor prices will be surveyed across the three regions. Field data on experimental protocols will be collected. Partial budgets will be constructed for dominance, marginal rate of return and sensitivity analyses. Gross margins and benefit cost ratios will be estimated.

*Sub-activity 5.2: Adoption and impact analysis for technological options developed:* Household data will be collected through surveys using structured questionnaires at the intervention communities. Focus group discussions will be held with lead farmers. Key informant interviews will also be held with key project staff, crop officers and other stakeholders. Farmers' fields will be regularly visited throughout the season to collect information on technology performance under farmer's conditions and identify constraints limiting adoption of introduced technologies/options. The sample farms will include those of farmers participating in the project activities, neighboring and field day attendees, and non-participant farmers as a control group. Both descriptive and econometric analyses will be used to assess the adoption and economic impacts.

*Sub-activity 5.3: Training core farmers on farming as a business:* Training modules on farm record keeping, farm plan, construction of simple budgets will be developed. Core farmers in the three regions will be trained.

*Sub-activity 5.4: Linking farmers to agro input dealers and aggregators:* A protocol for linking farmers to agro-input dealers and aggregators will be developed. Agro-input dealers and aggregators in each project district and region will be identified. Data on nature of business will be documented (name, location, type of

business, mode of operation, annual volume of transaction and pricing).

## 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Mobilize communities and form R4D	x	x	x	x								
2. Establish community level R4D-Mali	x	x	x	x								
3. Monitor market prices		x	x	x								
4. Characterize livestock value chains	x	x	x	x								
5. Conduct cost and benefit analysis		x	x	x								
6. Link farmers to markets		x	x	x								

## 8. Capacity building

	Male			Female		
	2014	2015	2016	2014	2015	2016
Farmers	600	700	900	200	400	500
Farmers' associations	30	35	45	15	20	25
Extension officers	10	10	10	10	10	10
Researchers	13	15	18	5	8	10
Input dealers	3	3	3	2	2	4
Policy makers	7	10	15	3	5	6
Development partners	3	4	6	2	3	4

## 9. Student training

	Male			Female		
	2014	2015	2016	2014	2015	2016
BSc		1	1		1	1
MSc students			1			1

## 10. Communication and dissemination

	2014	2015	2016
Workshops/meetings	21	27	20
Field days	1	1	1
Conference papers		1	2
Journal article			2

## 11. How are gender issues addressed?

Gender equity will be considered in revising the list of interested farmers, and identifying members of the R4D platforms.

## 12. Deliverables

- 1 Mobilize communities and form 4-6 community level R4D Platforms in Ghana – December 2014
- 2 Establish at least two community level R4D Platforms in Mali – December 2014
- 3 Report on feed markets and livestock value chains in Ghana – October 2014
- 4 MSc dissertations on livestock value chains in Ghana – December 2014
- 5 Cost benefit analysis of two interventions completed – October 2014
- 6 Link at least 100 farmers to markets – December 2014
- 7 Database on market prices for agricultural inputs and outputs updated – every month.
- 8 Report on market prices of agricultural inputs and outputs twice a year – June and December each year
- 9 Reports on value chain analyses on value chains identified in Koutiala and Bougouni/Yanfolila districts – March 2014

## 13. Expected outcomes (December 2014)

- Increased interaction among stakeholders through the R4D Platforms
- Research institutions use R4D Platforms and less of the linear approach to research

**14. 2014 Budget (\$)**

2014 Budget (7)			Partners						
Country	Activity	Budget Line	IITA	ICRAF	AMEDD	MOBIOM	ICRISAT	ILRI	IER
Ghana	Activity 1	Personnel	15000						
		Services	20000						
		Supplies	4000						
		Travel	6000						
		<b>Total</b>	<b>40000</b>						
	Activity 2	Personnel	0	11400	4000	3000	4400		
		Services	0	2000	6000	2000	0		
		Supplies	0	15600	1000	0	3600		
		Travel	0	25500	5500	3000	12000		
		<b>Total</b>	<b>0</b>	<b>54500</b>	<b>16500</b>	<b>8000</b>	<b>20000</b>		
	Activity 3	Personnel						7500	
		Services						3500	
		Supplies						5000	
		Travel						5000	
		<b>Total</b>						<b>21000</b>	
Mali	Activity 4	Personnel							5000
		Services							10000
		Supplies							2000
		Travel							5000
		<b>Total</b>							<b>22000</b>
	Activity 5	Personnel	10000						
		Services	14000						
		Supplies	6000						
		Travel	5000						
		<b>Total</b>	<b>35000</b>						
<b>Total</b>		<b>75000</b>	<b>54500</b>	<b>16500</b>	<b>8000</b>	<b>20000</b>	<b>21000</b>	<b>22000</b>	

## 2.2 Integrated Systems Improvement (Research Output 2)

### Work-package WP-2

#### 1. Title: Raising and sustaining productivity in cereal-legume cropping systems in northern Ghana

#### 2. Research team

<i>Name</i>	<i>Institution</i>	<i>Degree</i>	<i>Research interest</i>	<i>Role</i>
Asamoah Larbi	IITA	PhD	Crop-livestock, feeds	Principal Investigator (PI).
Saaka Buah	SARI	PhD	Plant nutrition, agronomy	Deputy PI.
Bekele Kotu	IITA	PhD	Agricultural economics	Economic analysis
Vicent Avornyo	UDS	PhD	Soil Science	Soil fertility management
Richard Opoku	UDS	PhD	Plant Pathology	Integrated pest management
Dominic Sobreh	IITA	MPh	Agronomy-vegetables	Field layout, data collection
Daniel Akakpo	IITA	MPh	Agronomy	Field layout, data collection
Shaibu Bedi	IITA	BSc	Agricultural economics	Surveys, monitoring, database
Tim Ellis	IWMI	PhD	Agric. water management	Lead, IWMI activities
Roger Kanton	SARI	PhD	Agronomy	Agronomy, UER
Francis Kusi	SARI	MPh	Entomology	Integrated pest management
Peter Asongre	SARI	MPh	Millet breeding	Millet agronomy
Issah Suguri	SARI	MPh	Post-harvest Science	Post-harvest Management
Julius Yirzagla	SARI	MPh	Systems agronomy	Cereal-legume cropping systems
Eastern Khana-Khali	PAR	MSc	Agricultural economics	Zia, fertilizer micro-dosing
Issahaku Zakaria	SNV	MSc	Agronomy	Sesame agronomy

#### 3. Summary

This work-package aims at raising and sustaining crop yield in the smallholder cereal-legume farming systems. Several options will be tested and disseminated to achieve this, including: scaling-up cereal-legume intercropping and rotation, crop diversification, reducing post-harvest grain losses and testing and dissemination of integrated soil fertility management. Cereal and legumes seeds are produced to scale-up improved cropping technologies.

#### 4. Research problem and justification

Small-scale, rainfed mixed farming predominates in the Guinea and Sudan savanna zones of northern Ghana. Most farmers grow cereals (e.g.: maize, rice, millet and sorghum), legumes (e.g.: groundnut, cowpea, soybean, Bambara nut, pigeon pea), and vegetables. The cereals and legumes are grown in pure or mixed stands. The vegetables are mostly grown as sole crops, but cereal-vegetable intercropping is practiced on a smaller scale. Cultivation is mainly by hand tools, with some farmers using animal draft implements. Women play a key role in agricultural production, both in food and cash crop production and in livestock husbandry, especially of small ruminants. They are also involved in post-harvest processing of crop and livestock products and off-farm income generating activities, as well as being responsible for collection of fuel wood, wild food species and water.

The principal constraints to smallholder rainfed crop production are: access to land and water resources; dependence on rainfall, which can be erratic and unpredictable, exacerbated by recurrent droughts; lack of knowledge of improved and appropriate technologies to increase productivity or expand the range of crops and crop rotations; lack of inputs, particularly quality seed; incidence of pests, diseases and weeds (notably *Striga* in sorghum and millet) and lack of control measures; high storage losses; lack of employment or other income generating activities outside the growing season; lack of access to formal credit; and, because of low yields and low incomes, a limited capacity to accumulate capital to expand their production enterprises. Information and knowledge exchange is limited, and enabling market, institutions and policies are lacking.

This work-package uses adaptive, community-based, participatory research to identify and promote appropriate technological and institutional options to intensify and diversify the smallholder cereal-legume systems to raise and sustain productivity.

#### 5. Specific objectives or research questions

- 1 Disseminate project results through publication of technical and non technical papers/leaflets
- 2 Test and disseminate cereal-legume strip cropping and crop rotation options to raise household crop and livestock production, incomes, improve soil fertility, and increase biomass for fodder for livestock
- 3 Evaluate and disseminate the 'Zia' and fertilizer micro-dosing method

- 4 Intercrop sesame with maize for income diversification
- 5 Develop, test, adapt and disseminate high-yielding crop varieties and good agronomic practices to intensify and diversify cereal-legume cropping
- 6 Test options to reduce post-harvest losses in cereals and legumes
- 7 Develop and test integrated soil fertility management strategies to improve grain yield in cereal cropping systems
- 8 Evaluate responses of rice varieties to N fertilizations

## 6. Work-plan and procedures

<b>Activity 1</b>	Publication of results from completed studies	
Lead Scientist(s)	Asamoah Larbi, Saaka Buah, Bekele Kotu	Institutions: IITA, SARI
Other Scientist(s)	Roger Kanton, Mumuni Abdulai, Francis Kusi, James Kombiok, Issah Sugri, Shaibu Mellon	
Location(s)	Tamale, Bolga, Wa	

### Procedures

*Sub-activity 1.1: Developing a database of completed experiments:* Second year data collection for three multi-locational agronomic trials were completed during the 2013 growing season. Data from those experiments will be put into a database which will be accessible to the responsible scientists.

*Sub-activity 1.2: Data analysis and publication of experimental results:* Responsible scientists for the three experiments referred to in sub-activity 1 will be assisted to analyze their data in consultation with a biometrician. The responsible scientists will draft papers for international peer reviewed journals. The papers will be circulated to the project scientists for review and submitted for publication through the project coordination office.

<b>Activity 2</b>	Scaling-up sustainable cropping practices: Cereal-legume strip cropping	
Lead Scientists(s)	Asamoah Larbi, Saaka Buah, Bekele Kotu	Institution: IITA, SARI
Other Scientist(s)	Daniel Akakpo, Dominc Sobreh, Shaibu Mellon, Mumuni Abdulai, Francis Kusi, Peter Asongre, Roger Kanton, Julius Yilzagla	
Students(s)	Abdul Rhaman Nurudeen	
Locations(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Previous projects such as the IITA-ILRI Crop-livestock, N2 Africa and AGRA Soil projects have identified several cereal-legume intercropping and rotations options that have potential to improve crop mix and crop rotations to raise farm incomes, enrich diets, improve soil fertility, suppress weeds, and increase biomass for fodder and for soil cover with cover crops and residues.

For example, previous research by IITA and ILRI showed that one of the best-bet options for integrating crop and livestock production in the dry savannahs is an improved strip cropping system involving 2 rows of densely planted improved sorghum to 4 rows of densely planted improved cowpea. Since the improved system involved 2/3 area under cowpea and 1/3 under sorghum, not only is the soil fertility improved but there is substantial reduction in the incidence of *Striga hermonthica*, which parasitizes sorghum and other cereals. However, most of the promising technologies have not been tested on-farm on a relatively large scale, and comparisons between the different intercropping and rotational systems under farmer conditions have been limited. Activities 2 and 3 aim at comparing and demonstrating different cereal-legume strip cropping and rotations under farmer conditions to address the constraints of low grain and fodder yield and, low soil nutrient status, high *Striga* incidence, and weak integration of the crop and livestock enterprises.

Households will be allowed to select from a basket of cereal-legume strip-cropping options listed below. Participating farmers will be given input and technical support to establish their plots. A basal dose of 100kg/ha NPK (15:15:15) will be given followed by a selective application of 20kg/ha N only on cereal rows and two sprays of insecticide only on the legumes. At harvest, crop residues from half of the plot will be removed to feed the farmers' sheep and goats, while residues on the other half will be retained for soil fertility improvement. Both biological (grain and fodder yield, weed biomass and diversity, soil chemical and



physical properties, soil fauna) and socio-economic (farmer preferences, labor input, gender distribution of chores) data will be collected. Impact of the technologies on household food production and income will be assessed. Seeds of the promising legumes and cereal will be multiplied in partnership with SEEDPAG and the Ghana Army.

*1. Options for sorghum-legume cropping systems*

2 rows of sorghum and 2 rows of cowpea; 2 rows of sorghum and 4 rows of cowpea  
2 rows of sorghum and 2 rows of groundnut; 2 rows of sorghum and 4 rows of groundnut  
2 rows of sorghum and 2 rows of soybean; 2 rows of sorghum and 4 rows of groundnut  
2 rows of sorghum and 2 rows of pigeon pea; 2 rows of sorghum and 4 rows of pigeon pea

*2. Options for early millet-legume cropping systems*

2 rows of early millet and 2 rows of cowpea; 2 rows of early millet and 4 rows of cowpea  
2 rows of early millet and 2 rows of groundnut; 2 rows of early millet and 4 rows of groundnut  
2 rows of early millet and 2 rows of soybean; 2 rows of early millet and 4 rows of groundnut  
2 rows of early millet and 2 rows of pigeon pea; 2 rows of early millet and 4 rows of pigeon pea

*3. Options for maize-legume cropping systems*

2 rows of maize and 2 rows of cowpea; 2 rows of maize and 4 rows of cowpea  
2 rows of maize and 2 rows of groundnut; 2 rows of maize and 4 rows of groundnut  
2 rows of maize and 2 rows of soybean; 2 rows of maize and 4 rows of groundnut  
2 rows of maize and 2 rows of pigeon pea; 2 rows of maize and 4 rows of pigeon pea

Records will be kept separately for type of strip crop and for each household. Both biological (grain and fodder yield, week biomass and diversity, soil chemical and physical properties, soil fauna) and socio-economic (farmer preferences, labor input, gender distribution of chores, market prices for the cereal and grain legumes) data will be collected. Exchange visits will be organized for partners within and between regions to promote information exchange. Impact of the technologies on household food production and income will be assessed (links with WP-1).

**Activity 3**

Scaling-up sustainable cropping practices: Cereal-legume rotations

Lead Scientists(s)

Asamoah Larbi, Saaka Buah, Bekele Kotu

Institution: IITA, SARI

Other Scientist(s)

Daniel Akakpo, Dominc Sobre, Shaibu Mellon, Mumuni Abdulai, Francis Kusi, James Kombiok, Issah Sugri, Peter Asongre, Roger Kanton, Julius Yilzagla

Students(s)

Abdul Rhaman Nurudeen

Locations(s)

Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri

**Procedures**

Households will select from a 'basket of cereal-legume rotation' options listed below. They will be given input and technical support to establish their plots. The crops will be rotated annually. Both biological (grain and fodder yield, week biomass and diversity, soil chemical and physical properties, soil fauna) and socio-economic (farmer preferences, labor input, gender distribution of chores) data will be collected. Data will be analyzed using households as replicates. Impact of the technologies on household food production and income will be assessed (links to WP-1).

*1. Options for sorghum-legume cropping systems*

Sorghum-cowpea  
Sorghum-groundnut  
Sorghum-soybean  
Sorghum-pigeon pea

*2. Options for early millet-legume cropping systems*

Early millet-cowpea  
Early millet-groundnut  
Early millet-soybean  
Early millet-pigeon peas

### 3. Options for maize-legume cropping systems

Maize-cowpea  
Maize-groundnut  
Maize-soybean  
Maize-pigeon pea

<b>Activity 4</b>	Scaling-up sustainable cropping practices: 'Zia' and fertilizer micro-dosing	
Lead Scientists(s)	Eastern Khana-Khali, Asamoah Larbi	Institution: PAS, IITA
Other Scientist(s)	Saaka Buah, Bekele Kuto, Daniel Akakpo, Dominc Sobreh, Shaibu Mellon, Francis Kusi, Peter Asongre, Roger Kanton, Julius Yilzagla	
Students(s)	Abdul Rhaman Nurudeen	
Locations(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

Zia farming is an innovative technology which involves the burial of manure/organic matter in holes/pits and planting the crop later on top of the pit. It improves water holding capacity and water infiltration and nutrient content of the soil. Fertilizer micro-dosing involves the application of small, affordable quantities of inorganic fertilizer with the seed at planting time. This is followed by top-dressing 6 weeks after planting. A combination of these two methods is referred to as 'Zia-micro dosing'.

In Ghana, 'Zia' has been successfully introduced on a limited scale to farmers in the East Gonja, East Mamprusi districts in the Northern region and Garu and Builsa districts in the Upper East region by the Presbyterian Agricultural Services. There is need for research on: 1) cost benefit analysis of the 'Zia' and fertilizer micro-dosing, 2) potential increase in grain yield of 'Zia' and fertilizer micro-dosing over farmers' practice in the Africa RISING intervention communities, and 3) comparative analysis of the effect of 'Zia' and fertilizer micro-dosing on maize, sorghum, millet and vegetables. The purpose of this activity is to evaluate and disseminate the 'Zia' and fertilizer micro-dosing techniques on-farm.

A randomized complete design with 30-50 households (replications) per treatment in each of 6 communities (2 community per region) will be used with the following treatments:

1. Farmers' practice (control)
2. Zia
3. Micro-dosing
4. Zia and micro-dosing

Fields of participating households will be divided into four plots. Treatments will be randomly assigned to plots. Maize will be used as the test crop. Input and output data will be recorded. Field days and exchange visits will be organized for farmers, research and extension staff, and policy makers.

<b>Activity 5</b>	Crop diversification in maize-based cropping systems: Maize-sesame intercropping	
Lead Scientists(s)	Asamoah Larbi, Saaka Buah, Issahaku Zakaria	Institution: IITA, SARI, SNV
Other Scientist(s)	Daniel Akakpo, Dominc Sobreh, Shaibu Mellon, Mumuni Abdulai, Francis Kusi, James Kombiok, Issah Sugri, Peter Asongre, Roger Kanton, Julius Yilzagla	
Locations(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

Mono-cropping of sesame (*Sesamum indicum*) is being promoted for cash to diversify smallholder income in northern Ghana. Although sesame can be intercropped with cereals (maize, sorghum, millet) to produce a sesame cash crop from the same fields, quantitative data on the cereal-sesame intercropping is scanty. The objective of this activity is to evaluate agronomic options for integrating sesame into maize, sorghum and millet cropping systems.

*Sub-activity 5.1: Fertilizer and time of sowing sesame into maize effects on grain yield and income:* A split-plot design replicated in 3-4 communities per region will be used. Main-plots are recommended fertilizer and higher fertilizer rates for maize; and sub-plots are: 1) Sole maize only, 2) Sole sesame 3) Maize + sesame

planted on the same day; 4) Maize + sesame planted one week after maize, and 5) Maize + sesame planted two weeks after maize. Maize will be planted in rows 75 cm apart and 40 cm within rows with 2 stalks per station at the beginning of the rainy season. Sesame will be planted midway between each maize row with within row spacing of 6 cm at 0, 1 and 2 weeks after planting maize.

*Sub-activity 5.2: Method of sowing sesame and maize planting density effects on labor requirements and grain yield:* A split-plot design replicated in 3-4 communities per region will be used. Main-plots will be hand broadcasting and drilling in row of sesame between maize. Main-plots are: hand broadcasting and drilling in rows. Sub-plots are maize planting density: 5, 10 and 15 plants/m<sup>2</sup>. Maize will be planted in rows 75 cm apart and 40 cm within rows with 2 stalks per station at the beginning of the rainy season. Sesame will be planted midway between each maize row with within row spacing of 6 cm at 2 weeks after planting maize. For both trials, data will be collected on growth of maize and sesame, light interception/leaf area index, weed diversity and biomass, grain yield of maize and sesame, soil temperature, soil moisture, and plant pests and diseases. Output and input data will be collected for cost benefit analysis.

<b>Activity 6</b>	Reducing post-harvest grain losses in cereals and legumes	
Lead Scientists(s)	Issah Sugri, Asamoah Larbi, Bekele Kuto	Institution: IITA, SARI
Other Scientist(s)	Shaibu Mellon	
Locations(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Two on-farm trials on the effect of type of storage and method of protection on grain quality of maize and cowpea started in 2013 at Tibonaayili, Gbanjong, Tibali, Bontingli, Bonia, Tekuru and Saboligo intervention communities will continue in 2014.

*Sub-sub-activity 6.1: Effect of jute and PIC sacks and grain protectants on maize and cowpea losses on-farm:* A trial on the effect of type of storage and method of protection on grain quality of maize and cowpea initiated in 2013 will continue in 2014 at Tibonaayili, Gbanjong, Tibali, Bontingli, Bonia, Tekuru and Saboligo intervention communities. Maize and cowpea grains were bulked from selected farmers during the harvesting season in October 2013. For each treatment, 40kg of maize and 30kg of cowpea were stored in jute and PICS sacks with or without grain protectants. Two commonly used grain protectants, Actellic Super EC and phostoxin were applied at the recommended rates. Actellic Super EC is a food-grade chemical containing 80g pirimiphos-methyl and 15g permithrin/liter as emulsifiable concentrate. The application dose provided by the manufacturer is 300ml in 15l of water for 20 maxi bags of maize. Post-harvest losses are being monitored over a period of 12 months.

*Sub-activity 6.2: Potential of hermetic plastic containers to reduce post-harvest losses on farm:* The effect of hermetic plastic tanks with or without grain protectants (Actellic Super EC and phostoxin) on post-harvest losses in maize and cowpea is being evaluated. Maize and cowpea grains were bulked during the harvesting season in October to November 2013. For each treatment, 40kg of maize and 20kg of cowpea were either stored in hermetic tanks with or without grain protectants. Post-harvest losses are being monitored till October 2014.

<b>Activity 7</b>	Testing and dissemination of improved crop varieties and agronomic practices using the 'mother-baby' approach	
Lead Scientists(s)	Asamoah Larbi, Saaka Buah, Bekele Kotu	Institution: IITA, SARI
Other Scientist(s)	Daniel Akakpo, Dominc Sobreh, Shaibu Mellon, Mumuni Abdulai, Francis Kusi, James Kombiok, Issah Sugri, Peter Asongre, Roger Kanton, Julius Yilzagla	
Locations(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Four 'mother-baby' trials started in 2013 to test and demonstrate crop variety and combinations of variety and agronomic options will continue for the second year. A split-plot design replicated in 4-6 communities per region will be used in each trial. There will be 30 'babies' per community for each mother trial. Grain yield and quality, soil chemical properties, and farmer preferences are being monitored. The mother trials are:

- Effects of recommended and higher fertilizer rates (main plots) on grain yield of maize varieties (sub-plots);
- Insecticide spraying regime - once or three times (main-plots) effects on grain yield of six cowpea varieties (sub-plots);
- Grain yields of early and late maturing soybean varieties (main plots) as affected by integrated soil fertility management (*Rhizobium* inoculation, phosphorus fertilizer and an organic fertilizer; sub-plots);
- Recommended (60kg/ha N-40kg/ha P<sub>2</sub>O<sub>5</sub>-40kg/ha K<sub>2</sub>O), and higher (90kg/ha N-40kg/ha P<sub>2</sub>O<sub>5</sub>-40kg/ha K<sub>2</sub>O) fertilizer rates (main-plots) effects on grain yields of 12 hybrid maize varieties (sub-plots).
- On-station multi-location evaluation of sorghum hybrids.

The 'mother' trials are managed by researchers and farmers to allow learning by experimentation, while the 'baby' trials are managed by the farmers. Field days and exchange visits will be organized to allow information exchange and dissemination. Data on grain and fodder yields, soil chemical composition, and farmers' preferences will be collected.

<b>Activity 8</b>	Evaluating integrated soil management options to improve crop grain yields in maize-legume systems	
Lead Scientists(s)	Saaka Buah, Asamoah Larbi	Institution: IITA, SARI
Other Scientist (s)	Peter Asongre, Roger Kanton, Julius Yilzagla	
Locations(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Three trials were started in 2013 to develop and test integrated soil fertility options to raise and sustain productivity in maize-legume rotations.

*Sub-sub-activity 8.1: Maize-soybean rotation:* An on-station maize-soybean rotation trial to evaluate the response of soybean to organic, mineral and *Rhizobium* inoculants started in 2013 and will continue. Treatments are: 1) soybean (no soil amendment), 2) soybean + inoculants, 3) soybean + inoculants + 60kg/ha P<sub>2</sub>O<sub>5</sub>, 4) soybean + inoculants + fertilisol, 5) soybean + inoculants + fertilisol + 60kg/ha P<sub>2</sub>O<sub>5</sub>, 6) soybean + inoculants + 25-60-30kg/ha as N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O, 7) continuous maize and 8) continuous soybean. The design is a randomized block with four replications. Plot size will be 4.5m x 5m (6-row plots). Soybean will be spaced 75cm x 5cm and maize at 75cm x 40 cm.

*Sub-sub-activity 8.2: Maize-groundnut rotations:* A maize-groundnut rotation trial to evaluate the response of groundnut to organic, mineral fertilizers and *Rhizobium* inoculants started in 2013 and will continue. The design is a randomized block with four replications. Treatments are: 1) groundnut alone (no soil amendment), 2) groundnut + inoculants, 3) groundnut + inoculants + 60kg/ha P<sub>2</sub>O<sub>5</sub>, 4) groundnut + inoculants + fertilisol, 5) groundnut + inoculants + fertilisol + 60kg/ha P<sub>2</sub>O<sub>5</sub>, 6) groundnut + inoculants + 25-60-30kg/ha as N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O continuous maize and 8) continuous groundnut. Plot size will be 4.5m x 5m (6-row plots). Groundnut will be spaced 60cm x 10cm and maize at 75cm x 40cm.

*Sub-sub-activity 8.3: Maize-cowpea rotations:* An on-station maize-cowpea rotation trial to evaluate the response of soybean to organic, mineral and *Rhizobium* inoculants started in 2013 and will continue. Treatments are: 1) cowpea alone (no soil amendment), 2) cowpea + inoculants, 3) cowpea + inoculants + 60kg/ha P<sub>2</sub>O<sub>5</sub>, 4) cowpea + inoculants + fertilisol, 5) cowpea + inoculants + fertilisol + 60kg/ha P<sub>2</sub>O<sub>5</sub>/ha), 6) cowpea + inoculants + 25-60-30kg/ha as N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O, 7) continuous maize and 8) continuous cowpea. The design will be a randomized block with four replications. Plot size will be 4.5m x 5m (6-row plots). Cowpea will be spaced 60 cm x 10 cm and maize at 75cm x 40cm.

Plant height, days to flowering, pods per plant, grain and stover yields and harvest index will be monitored in all trials.

<b>Activity 9</b>	Improving rice grain production: Effect of nitrogen fertilizer rates	
Lead Scientists(s)	Julius Yilzaga, Asamoah Larbi	Institution: SARI, IITA
Other Scientist(s)	Bekele Kotu, Dominc Sobreh, Shaibu Mellon	
Locations(s)	Samboligo, Bonia, Nangua	

## Procedures

A recent yield gap analysis in the rice-based cropping systems showed that nitrogen fertilizer and variety are key factors in increasing yield. The nitrogen requirements of the various varieties have not been studied on-farm. The purpose of this activity is to evaluate the responses of rice varieties to increasing fertilizer nitrogen levels under farmer conditions.

Grain yield responses of four improved rice varieties (Exvanka, Togo Mashall, Tox-233 and Nerica) plus a farmers' variety to increasing N levels (0, 40, 80 120 and 160kg/ha) will be tested on-farm at the Navrongo hub. Interested households will be selected and given seed and fertilizer. Grain yield and farmer preference will be recorded.

## 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Publication of papers		x	x	x								
2. Scaling cereal-legume strip-cropping		x	x	x	x	x	x	x	x	x	x	x
3. Scaling cereal-legume rotations		x	x	x	x	x	x	x	x	x	x	x
4. Evaluate 'Zia' and 'Micro-dosing'		x	x	x	x	x	x	x	x	x	x	x
5. Crop diversification: maize-sesame		x	x	x	x	x	x	x	x	x	x	x
6. Reducing post-harvest losses		x	x	x	x	x	x	x	x	x	x	x
7. Mother-baby trial		x	x	x	x	x	x	x	x	x	x	x
8. Test integrated soil fertility options	x	x	x	x								
9. Rice responses to N levels	x	x	x	x	x	x	x	x	x	x		

## 8. Capacity building

	Male			Female		
	2014	2015	2016	2014	2015	2016
Farmers	1000	1200	1400	500	700	800
Farmers' associations	6	12	15	3	5	7
Extension officers	7	10	15	2	5	8
Researchers	8	12	17	4	8	10
Input dealers	3	5	7	3	5	7
Policy makers	2	5	9	2	5	6
Development partners	3	5	6	3	5	5

## 9. Student training

	Male			Female		
	2014	2015	2016	2014	2015	2016
BSc	5	5	6	2	4	4
MSc students	2	3	5	2	2	2
PhD students	2	2	4	0	0	0
Interns/non-degree	4	8	6	2	4	4

## 10. Communication and dissemination

	2014	2015	2016
Workshops/meetings	Mar-Jun	Mar-Jun	Mar-Jun
Field days	Sep-Oct	Sep-Oct	Sep-Oct
Conference papers	May-Jul	May-Jul	May-Jul
Journal article	Mar-May	Sep-Nov	Sep-Nov
Others (Exchange visits)	Sep-Nov	Sep-Nov	Sep-Nov

## 11. How are gender issues addressed?

Gender issues are addressed through creation of gender awareness and gender equity in all the project communities. Gender equity issues are mainstreamed in all project meetings. Barriers-to-participation are reduced by offering gender sensitive interventions and the use of appropriate styles and language in all capacity building activities. Women interest groups (WIGs) are promoted and linked to credit.

## 12. Deliverables

- 1 At least two papers submitted to ISI journal for publication – August 2014
- 2 Cereal-legume strip cropping tested by at least 100 households – October 2014
- 3 Cereal-legume rotations tested by at least 100 households – October 2014
- 4 Zia' and 'Fertilizer Micro-dosing' tested and demonstrated on-farm – October 2014
- 5 One crop diversification option tested on-farm – October 2014
- 6 A technology identified to reduce on-farm maize and cowpea grain losses by 15% – October 2014
- 7 At least 4 new technologies disseminated with farmers through 'mother-baby' trials – December 2014
- 8 Two integrated soil fertility management option for maize-cereal systems identified-December 2014.
- 9 Fertilizer N rate trials started on farm – December 2014

## 13. Expected outputs (by December 2014)

- Published journal papers – June 2015
- Farmer preferred cereal-legume rotations – December 2015
- A model for crop diversification – December 2015
- Farmer-preferred options to reduce post-harvest losses in cereal and legume grains – March 2015
- Integrated soil fertility options for cereal-legume production – June 2015
- At least 2 PhD and 3 MSc dissertations completed
- At least 1000 farmers, 40 extension officers and 10 researchers trained
- Recommended N fertilizer rate for rice varieties – June 2016

## 14. Expected outcomes

- Households in the intervention communities adopt cereal-legume strip-cropping and rotation
- Households integrate cash crops into cereal cropping systems to diversify income
- Households adopt improved storage practices to reduce post-harvest losses of grains
- More households are integrating legumes into their cropping systems

## 15. Potential impact of outcome

<i>Item</i>	<i>Impact</i>
Household crop production	Reduction in food insecurity.
Household livestock production	Meat, milk and egg outputs increase by 15%.
Environment (on-farm soil properties)	On-farm soil N and infiltration rate increase by 10%.
Household income	Household income increases by 15% through increased sale of products.
Household nutrition (women and children)	Dietary diversity index increases by 20% through intake of diversified products, especially legumes.

**16. 2014 Budget (US\$)**

	Budget Line	IITA	SARI
Activity 1	Personnel		5000
	Services		2000
	Supplies		1000
	Travel		2000
	<b>Total</b>		<b>10000</b>
Activity 2	Personnel	20000	
	Services	3000	
	Supplies	10000	
	Travel	2000	
	<b>Total</b>	<b>35000</b>	
Activity 3	Personnel	21000	
	Services	4000	
	Supplies	8000	
	Travel	2000	
	<b>Total</b>	<b>35000</b>	
Activity 4	Personnel	17000	
	Services	2000	
	Supplies	5000	
	Travel	1000	
	<b>Total</b>	<b>25000</b>	
Activity 5	Personnel	18000	
	Services	2000	
	Supplies	9000	
	Travel	1000	
	<b>Total</b>	<b>30000</b>	
Activity 6	Personnel	20000	
	Services	2000	
	Supplies	5000	
	Travel	3000	
	<b>Total</b>	<b>30000</b>	
Activity 7	Personnel	12000	7000
	Services	15000	500
	Supplies	4000	4000
	Travel	500	500
	<b>Total</b>	<b>18000</b>	<b>12000</b>
Activity 8	Personnel		8000
	Services		6000
	Supplies		3000
	Travel		3000
	<b>Total</b>		<b>20000</b>
Activity 9	Personnel		3000
	Services		1000
	Supplies		4000
	Travel		2000
	<b>Total</b>		<b>10000</b>
	<b>Grand total</b>	<b>173000</b>	<b>52000</b>

## Work-package WP-3

### 1. Title: Biological control of aflatoxins in maize and groundnut with Aflasafe Ghanaian product GH01

### 2. Research team

Name	Institution	Degree	Research interest	Role
Ranjit Bandyopadhyay	IITA	PhD	Mycotoxin management	Guidance
Joseph Atehnkeng	IITA	PhD	Mycotoxin management	Coordination
Daniel Agbetiamah	KNUST	MSC	Mycotoxin management	PhD student
Richard T. Awuah	KNUST	PhD	Mycotoxin management	Supervision PhD student

### 3. Summary

The project aims to evaluate a biocontrol product (aflasafe GH01) which is a mixture of different strains of *Aspergillus flavus*, native to Ghana for the mitigation of aflatoxins in maize and groundnuts. Data will be collected from field efficacy trials to support the registration of the biocontrol product for use in Ghana. Training workshops will be conducted for farmers, agricultural extension agents and other partners to enhance their capacity for aflatoxin management and awareness. The outcome will be availability of a biocontrol product that will reduce aflatoxin contamination in maize and groundnut thereby improving health of Ghanaians and enhancing income opportunities for participants in maize and groundnut value chains.

### 4. Research problem and justification

Aflatoxins are toxic metabolites, with carcinogenic properties, produced by *Aspergillus flavus*, *A. parasiticus* and *A. nomius*. Maize and groundnut are particularly prone to aflatoxin contamination in Ghana. Presence of aflatoxins in crops compromises the safety of food and feed supplies and adversely impacts human and animal health resulting in deaths as well as significant economic losses to producers.

Even though postharvest management strategies and storage conditions to minimize contamination are known, these strategies are not completely effective since much of the contamination begins before harvest. Sustainable management of aflatoxin contamination should thus begin in the field. One strategy that has consistently achieved successes over the years is the biological control of aflatoxin via the use of native atoxigenic *A. flavus*. This involves careful selection and introduction of highly competitive and widely adapted strains of atoxigenic *A. flavus* to soils prior to flowering of susceptible crops. The atoxigenic strains out-compete the toxigenic strains thereby reducing toxin contamination. Atoxigenic strains of *Aspergillus* sect. *flavi* belonging to widely distributed and diverse genetic groups were selected in a previous project, but quantitative data on their efficacy in farmers' fields is limited.

### 5. Objectives

- 1 To sensitize growers and extension agencies about the dangers of aflatoxins and the potential of biocontrol for producing maize and groundnut with acceptable levels of aflatoxins
- 2 To train farmers and other crop value chain participants in aflatoxin management
- 3 Collect efficacy data to satisfy biopesticide pre-registration requirements
- 4 Develop best use practices for biocontrol in target regions and cropping systems
- 5 To train a Ghanaian student in aflatoxin biocontrol research for institutionalizing aflatoxin management capacity in Ghana

### 6. Work-plan and procedures

<b>Activity 1</b>	Training of farmers and extension agencies	
Scientist(s)	Joseph Atehnkeng, R.T. Awuah, Ranajit Bandyopadhyay	Institution: IITA, KNUST
Partner(s)	MoFA and Food Research Institute (FRI)	
Student(s)	Daniel Agbetiamah	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

An awareness and sensitization workshop will be held for regional and district directors of MoFA in all the three regions (Northern, Upper West and Upper East) to make them aware of the intended work-package in their regions and districts to solicit the participation of their staff. Further, three awareness and sensitization



workshops (one in each region) will be conducted for farmers and AEAs of MoFA to highlight aflatoxins as a problem, its causes (how, where and affected crops), signs and symptoms on crops, effects on human and animal health as well as trade, management strategies with focus on biological control, etc. Farmers, consumers, staff of MoFA and regulatory agencies will be sensitized about the potential of biocontrol for producing maize and groundnut with acceptable levels of aflatoxins. Key resource persons from IITA biocontrol team, the KNUST, FRI and MoFA with expertise in the field of aflatoxin research will be invited to make presentations. A total of 9, comprising 3 regional and 6 district, directors of agriculture will be sensitized. In addition, 100 farmers and 25 AEAs will also be invited to the workshops. Focus group discussions on the topic will also be held at the community level. In the Northern Region, group discussions will be organized in Duko, Tibali in Savelugu-Nanton District and Tibognayili in Tolon-Kumbugu District. In the Upper West Region group discussions will be organized in Passe, Zanko in Wa West District and Natoduori in Nadowli District. In Upper East Region group discussions will be organized in Samboligo in Bong District and Nyangua and Bonia in Kassena-Nankana District. A list of all participants in each meeting will be made and leaflets on aflatoxin biocontrol and other methods of aflatoxin management will be distributed to participants. Panel discussions will also be held on local and national FM radio and television stations with farmers and other stakeholders pre-informed through text messages on phone about such programs.

We will also coordinate this activity with ICRISAT that is working on aflatoxin management in groundnut in Africa RISING project.

<b>Activity 2</b>	Test field efficacy of biocontrol strains	
Scientist(s)	Joseph Atehnkeng, Ranajit Bandyopadhyay	Institution: IITA
Partner(s)	Farmers, MoFA, KNUST	
Consultant(s)	Richard T. Awuah	
Student(s)	Daniel Agbetiamah	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Farmers and/or farmer associations and sites for on-farm efficacy evaluation of the biocontrol agent will be identified. A total of 60 fields comprising 30 treated maize fields with 10 fields per region and 30 groundnut fields with 10 fields per region. For each treated fields an untreated field will be identified to serve as control. Field sizes will range between 0.5ha and 2ha. Each field will be considered a replicate. The trials will be conducted on crops grown by farmers as per their normal agronomic practices. Farmers will be sensitized and trained on when to apply and mode of application of the biocontrol agent, as well as, how it works to reduce aflatoxins in crops. Field soils samples will be collected prior to application of the biocontrol agent to measure the native population structure of *A. flavus* and after harvesting to measure the changes in the *Aspergillus* community structure due to biocontrol product application. Further, crop (grain) samples will also be collected to conduct laboratory analysis on the efficacy of the biocontrol products. This procedure will be carried out for at least two successive growing seasons. Field efficacy data collected will be used to satisfy requirements for pre-registration of the biocontrol agent as a biopesticide.

In addition to the 60 fields in the Africa RISING areas in northern Ghana mentioned above (funded by Africa RISING), efficacy trials will be also conducted in the middle belt (funded by another complementary project – the Meridian/PACA/BMGF regional biocontrol development). The country-wide efficacy trials are required to determine the efficacy of biocontrol in several agro-ecozones.

<b>Activity 3</b>	Increase human resource capacity	
Scientist(s)	Ranjit Bandyopadhyay, Joseph Atehnkeng	Institution: IITA
Partner(s)	Farmers, MoFA, KNUST	
Consultant(s)	Richard T. Awuah	
Student(s)	Daniel Agbetiamah	
Location(s)	Kumasi	

### Procedures

A PhD student from KNUST has been identified to work on the project. His name is Daniel Agbetiamah and his university supervisor is Prof. Richard Awuah. Research topics relevant to aflatoxin management have

been assigned and student supervised in their thesis research to build their capacity to conduct aflatoxin research. The student will conduct bulk of the laboratory and field research to generate data for registering Aflasafe in Ghana. His field research will be in Ghana while laboratory analysis will be conducted at IITA-Ibadan (due to lack of adequate research infrastructure necessary for conducting microbiological and chemical analysis of the samples in Ghana). Staff of partner institutions such as universities and CSIR will also be trained in the principles and methodologies followed in aflatoxin biocontrol in the research to development continuum.

## 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Identification/sensitization of partners	x	x	x	x	x							
2. Selection of areas, farmers and fields		x				x				x		
3. Training of farmers & AEAs		x	x									
4. Field application of biocontrol			x				x				x	
5. Sample collection			x	x	x		x	x	x		x	x
6. Sample analysis & data collection				x	x	x		x	x	x		x
7. Protocols for best use practices					x							
8. Preparation efficacy report											x	x
9. Building human resource capacity	x	x	x	x	x	x	x	x	x	x	x	x

## 8. Capacity building

	Male			Female		
	2014	2015	2016	2014	2015	2016
Farmers	40	80	100	20	30	50
Farmers' associations	10	20	30	1	2	20
Extension officers	18	25	50	20	30	40
Researchers	2	4	4	2	2	4
Input dealers	0	2	5	-	-	-
Policy makers	5	10	10	2	4	5
Development partners	1	3	4	1	1	2

## 9. Student training

	Male			Female		
	2014	2015	2016	2014	2015	2016
PhD students	1	0	0	0	0	0

## 10. Communication and dissemination

	2014	2015	2016
Workshops/meetings	April - June	April - June	April - June
Field days	Sept - Oct	Sept - Oct	Sept - Oct
Conference papers	May - June	May - June	May - June
Journal article			May - June

## 11. How are gender issues addressed?

Approximately equal numbers of female farmers as male farmers will be considered when selecting farmers for field trials. In like manner, female AEAs with outstanding field performances will be given priority and selected for training workshops to in turn train farmers in the biocontrol project. Further, female experts in the field of aflatoxin research in Ghana and elsewhere will be invited from time to time as consultants and, female students with interest in research on mycotoxin management in crops will also be given equal priority as male students for further training.

## 12. Deliverables

- 1 Report on farmers' awareness of aflatoxins as a food safety concern and its management
- 2 Weekly radio and television messages on effects of aflatoxins and their management
- 3 Results of efficacy trials in farmers' fields
- 4 Protocol for best use practices indicated in project progress report

**13. Expected outputs**

- Efficacy of biocontrol products demonstrated for the reduction of aflatoxins in maize and groundnuts (May, 2015)
- Increase public awareness and sensitization of aflatoxin as a health menace in food and feed crops (Aug., 2015)
- Efficacy and product data available for pre-registration of atoxigenic strains as biopesticides (July, 2016)
- An aflatoxin biocontrol product, GH01 available for registration and use in Ghana (Aug., 2016).
- Students and staff trained for conducting aflatoxin research (ongoing)

**14. Expected outcomes**

- Farmers and value chain actors have adopted biocontrol and management practices that minimize aflatoxins in maize and groundnut in the field and during storage
- Extension officers have included aflatoxin management in their extension messages to farmers

**15. Potential impact of outcome**

<i>Item</i>	<i>Impact</i>
Household crop production	Reduced risk of aflatoxin contamination in maize and groundnut.
Household livestock production	Reduced risk of exposure of livestock to aflatoxin contamination.
Environment (on-farm soil properties)	Sustainable production of better quality maize and groundnut using an environment friendly natural biocontrol product
Household income	Increased household income for maize and groundnut farmers through sale of aflatoxin safe crop at a premium in the market
Household nutrition (women and children)	Increased nutrition through reduced exposure to anti-nutritional aflatoxin contamination and increased consumption of safe food for women and children.

**16. 2014 Budget (US\$)**

	Budget Line	IITA
Activity 1	Personnel	8,000
	Services	5,000
	Supplies	0
	Travel	2,000
	<b>Total</b>	15,000
Activity 2	Personnel	20,000
	Services	8,000
	Supplies	10,000
	Travel	9,000
	<b>Total</b>	47,000
Activity 3	Personnel	10,000
	Services	0
	Supplies	0
	Travel	3,000
	<b>Total</b>	13,000
<b>Grand total</b>		<b>75,000</b>

## Work-package WP-4

### 1. Title: Integrating vegetables into cereal-legume cropping systems in Ghana

### 2. Research team composition

<i>Name</i>	<i>Institution</i>	<i>Degree</i>	<i>Research interest</i>	<i>Role</i>
Abdou Tenkuano	AVRDC	PhD	Breeding	Contact – AVRDC
Klaus Fleissner	AVRDC	PhD	Production systems	Principal Investigator (PI)
Regine Kamga	AVRDC	MSC	Agronomy/scaling	Lead activities 1-3
Asamoah Larbi	IITA	PhD	Crop-livestock, agronomy	Coordination, Deputy PI
Brain Akakpo	IITA	MPh	Agronomy	Activities 1-3
Shaibu Bedi	IITA	BSc	Agricultural economics	Surveys
Dominic Sobreh	IITA	BSc	Agronomy	Vegetable production
Yelipoie Comfort	IITA	BSc	Agronomy	Vegetable production
Saaka SJ Buah	SARI	PhD	Crops, soils	Agronomy
Marshak Abdulai	SARI	PhD	Breeding	Vegetable seed
Francis Kusi	SARI	MPh	Pest management	Pest Management
Francis Appiah	KNUST	PhD	Food science, post-harvest	Food Science, training
Richard Agyare	SARI	MPh	Vegetable breeding	Breeding, seed production
Salim Lamini	SARI	MPh	Plant pathology	Pest management

### 3. Summary

This work-package aims at developing integrated vegetable production in cereal-legume cropping production systems as well as processing and storage for both home consumption and for sale, especially during December and March. It will: (i) assess and improve vegetable and legume variety and seed supply systems for cereal-based systems, (ii) develop best production practices for cereal-legume-vegetable crop integration, and (iii) strengthen the capacities of the actors (farmers, extension and research staff) associated with cereal-legume-vegetable systems. At the end of the project, farmers will have access to improved technologies for producing, processing and storage of vegetables.

### 4. Research problem and justification

Vegetable production for cash and household consumption is among the major farming activities in the Northern, Upper East and Upper West regions. Farmers produce vegetables throughout the year both under rainfed and irrigation. Major vegetables produced include: onion, okra, tomato, pepper and leafy vegetables. They can either be cultivated as sole crop or in association with cereals (maize, rice, sorghum or other cereals) and legumes (cowpea, pigeon pea, lablab, mung bean or other legumes) in mixed cropping during the main cropping season, in rotation during the fallow season, or as relay crop during the transition periods preceding or succeeding the main cropping season. Productivity of rainfed and irrigated vegetables are generally low due to several constraints, especially use of low yielding varieties, poor management practices (low planting densities in pure and mixed stands, pest and disease control, and nursery practices), intermittent drought, and low soil fertility. Others are: seasonal price fluctuation and considerable post-harvest losses occurring right from the field, during transportation, and after delivery to the market.

### 5. Objectives

- 1 Determine the adequacy of vegetable and legume seed availability, supply and quality in target communities
- 2 Improve vegetable and legume seed production and distribution in target communities
- 3 Provide technologies to intensify and improve monoculture vegetable production
- 4 Compare different vegetable-cereal-legume production and agronomic management options
- 5 Undertake cost-benefit analysis of vegetable production packages
- 6 Identify an MSc student to use activity for dissertation research
- 7 Assess system productivity gains associated with cereal-legume-vegetable integration
- 8 Assess system income gains associated with cereal-legume-vegetable integration
- 9 Assess system contribution to dietary diversity of households
- 10 Equip households with knowledge on production practices that optimize returns in the field
- 11 Assess system productivity gains associated with cereal-vegetable integration
- 12 Assess system income gains associated with cereal-legume-vegetable integration

## 6. Work-plan and procedures

<b>Activity 1</b>	Improve vegetable and legume seed supply systems	
Lead Scientist(s)	Klaus Fleissner, Regine Kamga	Institution: AVRDC
Other Scientist(s)	Francis Kusi, Issah Sugri, Dominic Sobreh, Asamoah Larbi	
Student(s)	Martha Egyiri	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

At least 50 Households selected for intervention trials in each of the two districts for each of the three regions will be appraised on seed supply and post harvest issues in order to develop community-based systems for production, storage and delivery of quality vegetable and legume seeds. To raise awareness, demonstration plots for legumes and vegetables, which are not familiar to farmers, will be established in each of the two districts of the three regions.

Project trained enumerators based in the districts will collect relevant information on post harvest and storage issues as well as on sources, adequacy of supply and quality of vegetable and legume seeds through questionnaires and focus group discussions. This work will form part of the thesis research of an MSc student to be identified (from Kwame Nkrumah University of Science and Technology).

A socio-economist will be involved in the analysis of the appraisals and based on the results of the analysis and documented previous experiences from community-based seed production, suitable strategies for the development of community-based seed production systems in the project target area will be developed and tested in 2015 and 2016.

<b>Activity 2</b>	Test and disseminate technologies to intensify vegetable mono-cropping	
Lead Scientist(s)	Klaus Fleissner, Regine Kamga	Institution: AVRDC
Other scientist(s)	Asamoah Larbi, Francis Kusi, Issah Sugri, Dominic Sobreh, Salim Lamini, Brain Akakpo, Shaibu Bedi, Yelipoie Comfort	
Consultant(s)	Mashark Abdulai	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Participatory testing and diffusion of promising new vegetable cultivars in combination with recommended management practices will be carried out in on-farm experiments to demonstrate and deliver high value, multiple disease-resistant and nutrient-dense vegetable cultivars and improved production techniques to the beneficiaries. A participatory evaluation of new legume species to identify potentially interesting legumes for farmers will be done during a farmer field day at selected demonstration plots.

Four vegetable crops will be compared across subsets of 30-50 households (depending on crop preference and seed availability) in each of the three target regions comparing farmer's practice vs. recommended practice. The crops to choose from are three leafy vegetables (Amaranth for the Upper West Region, Jute Mallow for the Northern Region and Roselle for the Upper East Region), three fruit vegetables (Okra in all three regions, African eggplant in the Northern Region and Tomato in the other two regions), and one spice vegetable (Pepper, in all three regions).

Data will be collected on productivity (yield) and market value (income generating potential) and utilization (contribution to dietary diversity) of the tested vegetables. It is intended that this work will form part of the thesis research of an MSc student to be identified.

<b>Activity 3</b>	Test, evaluate and disseminate promising technologies to intensify integrated cereal-legume- vegetable production	
Lead Scientist(s)	Klaus Fleissner, Regine Kamga	Institution: AVRDC
Other scientist(s)	Asamoah Larbi, Francis Kusi, Issah Sugri, Dominic Sobreh, Salim Lamini, Brain Akakpo, Shaibu Bedi, Yelipoie Comfort, Hamid Seidu	
Consultant(s)	Mashark Abdulai	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo,	

### Procedures

As above, participatory testing will be carried out to assess the suitability of selected high value, multiple disease-resistant and nutrient-dense vegetable cultivars for cultivation under mixed cropping regimes with cereals – maize, sorghum, or millet and legumes (cowpea, pigeon pea, lablab or mung bean). There will also be sole vegetable and cereal plots to serve as checks to assess the performance of the vegetables in the integrated systems.

Four vegetable crops will be compared in different mixed cropping regimes with cereals and legumes across subsets of 30-50 households (depending on crop preference and seed availability) in each of the three target regions comparing if possible farmer planting and management practice vs. recommended practice. Offered vegetables will be the same in all three regions, consisting of Okra, African eggplant, Roselle and Pepper.. Combination of crops will vary across households depending on preference and seed availability.

Data will be collected on productivity (yield) and market value (income) and utilization (contribution to dietary diversity) for the vegetable component and overall cropping system. It is expected that this work will form part of the thesis research of an MSc student to be identified.

<b>Activity 4</b>	Carry out hands-on training on best production practices and post harvest handling
Lead Scientist(s)	Klaus Fleissner
Other Scientist(s)	Asamoah Larbi, Francis Kusi, Issah Sugri, Dominic Sobreh, Salim Lamini, Brain Akakpo, Shaibu Bedi, Comfort Yelipoi, Hamid Seidu
Consultant(s)	Mashark Abdulai, Francis Appiah
Student(s)	Martha Agyiri
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri

### Procedures

It is proposed to cluster demonstration and training activities around best practices hubs to be set-up in each of two regions (Northern and Upper East) each connecting to target communities in each of two districts per region. Farmers (households) will be trained and extension staff's knowledge reinforced in intensive vegetable production, integration of vegetables into cereal-legume production systems, community based seed production and storage, post-harvest management. Field days and exchange visits (possibly to neighboring countries) will be used (a) to raise awareness on vegetable-enriched food preparations that preserve or enhance nutritional content, particularly for women and children, (b) to raise awareness on exotic and unfamiliar vegetables and legumes and (c) exposure to simple post-harvest handling options that reduce losses and optimize returns in the market. Stakeholder workshops will be held at the beginning of the project to refine work plans and at the end of the project to share and document achievements and lessons.

<b>Activity 5</b>	Mentor and supervise undergraduate and graduate students
Lead Scientist(s)	Klaus Fleissner Institution: AVRDC
Other Scientist(s)	Asamoah Larbi, Francis Kusi, Issah Sugri, Dominic Sobreh, Salim Lamini, Brain Akakpo, Shaibu Bedi, Comfort Yelipoi, Hamid Seidu
Consultant(s)	Mashark Abdulai, Francis Appiah
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri

### Procedures

Undergraduate and graduate (MSc and PhD) students will be identified in consultation with collaborating partners at Kwame Nkrumah University of Science and Technology and University for Development Studies. The potential students will be placed with the Africa RISING regional teams, with the mentoring and under the supervision of the scientists assist in the monitoring of field trails and collect and analyze data from the research activities for his or her dissertation research.

## 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Seed systems appraisal and analysis	x	x	X	X								
2. Community based vegetable and legume seed production						X	X			X	X	
2. Legumes demonstration plots												
			X			X	X					
3. Improve vegetable mono-cropping systems	x	x	X	x	x	x	x	x	x	x	x	x
4. Integrate vegetable in cereal-legume systems	x	x	x	x	x	x	x	x	x	x	x	x
5. Build capacity - farmers, extensionists		x	x	x	x	x	x	x	x	x	x	x
6. Train graduates		x	x	x	x	x	x	x	x	x	x	x

## 8. Capacity building:

	Male			Female		
	2014	2015	2016	2014	2015	2016
Farmers	200	300	350	100	150	200
Farmers' associations	5	8	3	4	6	2
Extension officers	10	10	12	3	6	10
Researchers	5	10	10	3	6	10
Input dealers	15	20	30	5	10	10
Policy makers	5	8	10	1	2	4
Development partners	2	3	3	2	2	3

## 9. Student training

	Male			Female		
	2014	2015	2016	2014	2015	2016
BSc	3	3	3	2	2	2
MSc students	1	1	1	1	1	1
PhD students	1	1	1	1	1	1
Interns/non-degree	4	4	4	2	2	2

## 10. Communication and dissemination

	2014	2015	2016
Workshops/meetings	2	2	2
Field days	6	6	2
Conference papers	1	1	1
Journal article	0	3	1
Others (theses, variety description sheets, seed production protocols)	0	3	5

## 11. How are gender issues addressed?

Households will be selected from farming communities with a focus on women and youth, following a participatory appraisal process. The selected participants will be involved in the daily operations of the project at the field level using an immersion approach.

## 12. Deliverables

- 1 Report on vegetable seed systems and post harvest issues in intervention communities
- 2 Farmers have been exposed to a variety of legume species
- 3 Agronomic packages for vegetable production in pure stands tested in at least 10 villages
- 4 Agronomic packages for vegetable production in mixed stands with cereals and legumes tested in at least 10 villages
- 5 Best practices of vegetable production disseminated to about 300 men and women
- 6 About 200 farmers trained in intensive vegetable production and post-harvest management
- 7 At least 4 exchange visits between farmers organized by September 2016

- 8 At least 6 extension staff trained by September 2016
- 9 At least 5 field days organized per year to raise awareness on best production practices, legumes species, post-harvest and dietary diversity
- 10 At least 2 MSc students and 6 undergraduate students trained by 2016
- 11 At least 2 journal articles submitted for publication by 2016

### 13. Expected outputs

- Technologies for intensify vegetable production under sole and cereal-legume-vegetable cropping systems evaluated and disseminated
- Capacities of actors (farmers, extension and research staff...) associated with cereal-vegetable systems strengthened

### 14. Expected outcomes

- More farmers integrate vegetables and legumes into their cereal cropping systems.
- Farmers adjust their vegetable cropping patterns to increase the number of plants per unit area

### 15. Potential impact of outcome

<i>Item</i>	<i>Impact</i>
Household crop production	Increased access by farmers to quality vegetable seed systems along with introduction of innovations for optimal systems agronomic performance; Increased awareness, establishment of producer groups and strengthening of existing producer groups that lead to social benefits such as better ability to arrive at group consensus, basing farm decisions on observation, and confidently speak in public/groups about adapted farming systems.
Environment (on-farm soil properties)	Appropriate resource management and crop variety choices supported by a sound behavioral change strategy, notably to conserve water and ban practices that are detrimental to the environment and the health of consumers
Household income	Increased productivity of high-value vegetables and household incomes and livelihood status in intensified cereal-vegetable production systems
Household nutrition (women and children)	Better understanding of consumer preferences and enhanced value chains that provide more nutritious and safer vegetables to target communities for a balanced diet



**16. 2014 Budget (US\$)**

	Budget Line	AVRDC	IITA
Activity 1	Personnel	5000	5000
	Services	2000	3000
	Supplies	4000	4000
	Travel	1000	2000
	<b>Total</b>	<b>12000</b>	<b>14000</b>
Activity 2	Personnel	5000	5000
	Services	4000	4000
	Supplies	3000	3000
	Travel	2000	2000
	<b>Total</b>	<b>14000</b>	<b>14000</b>
Activity 3	Personnel	6000	7000
	Services	4000	3000
	Supplies	3000	4000
	Travel	2000	3000
	<b>Total</b>	<b>15000</b>	<b>17000</b>
Activity 4	Personnel	9000	4000
	Services	2000	2000
	Supplies	1500	1000
	Travel	2000	1000
	<b>Total</b>	<b>14500</b>	<b>8000</b>
Activity 5	Personnel	2000	3000
	Services	2000	2000
	Supplies	500	2000
	Travel	1000	1000
	<b>Total</b>	<b>5500</b>	<b>8000</b>
<b>Grand Total</b>		<b>61000</b>	<b>61000</b>

## Work-package WP-5

### 1. Title: Improving farm and field productivity and profitability in Mali

#### 2. Research team

<i>Name</i>	<i>Institution</i>	<i>Degree</i>	<i>Research interest</i>	<i>Role</i>
Birhanu Zemadim	ICRISAT	PhD	Agronomy	Principal Investigator (PI)
Albert Rouamba	AVRDC	PhD	Vegetable breeding	Deputy PI
Keriba Coulibaly	AVRDC	MSc	Agricultural economics	Managing trials
Gatien Falconnier	ICRISAT	MSc	Farming systems	Managing trial
Catherine Dembele	ICRAF	PhD	Agroforestry	Managing trials, data analyses
Fatoumata Traoré	ICRAF	BSc	Leafy vegetable	Monitoring trials
Mary Ollenburger	WUR	MSc	Farming systems	Managing trials,
Eva Weltzien	ICRISAT	PhD	Sorghum breeding,	Seed production, monitoring trials
Ousmane Sanogo	IER	PhD	Farming systems	Market study and household characteristics
Katrien Descheemaeker	WUR	PhD	Farming systems	Farming systems
Jeroen Groot	WUR	PhD	Farming systems	Farming systems analysis
Asamoah Larbi	IITA	PhD	Crop-livestock systems	Coordination
Joachim Binam	ICRAF	PhD	Socio-economy	Economic evaluation
Odjouma Samaké	ICRAF	MSc	Agroforestry	Managing trial
Bréhima Koné	ICRAF	MSc	Agroforestry	Managing trial

#### 3. Summary

This work package aims at improving productivity and profitability of farming system components. It combines on-farm participatory testing and evaluation of integrated innovations modeling of productivity, profitability and sustainability of farm systems and their components and presentation and discussion of the results to participating farmers, farmers' organizations and local partners. Expected outputs are: (1) yield and cost-benefit estimates for integrated intensification options available, (2) information about monthly market prices and selected value chains of livestock, crop and tree products and yearly basic household characteristics of AR villages available and (3) estimates of farm efficiency (economic and agronomic) and sustainability of different configurations of farm system components and farm development scenarios available. Capacity of farmers' organizations, development partners and scientific personnel in testing, evaluating and dissemination integrated innovations will be strengthened. Furthermore, wherever possible, BSc, MSc and PhD students will be strongly involved in data collection and analyses.

#### 4. Research problem and justification

Options for improving crop-livestock interaction and increasing efficiency were cited during the initiation workshops and through feedback as good opportunities for farmers, but have not been extensively studied so far. There is thus a strong need to identify the potential for technologies to improve productivity of farm system components, but also to identify how farm system components can be more efficiently linked and integrated to achieve improved, whole farm productivity.

A number of opportunities and constraints were cited and classified by stakeholders during village and district level consultation meetings in 2012 and 2013, including: (1) market opportunities for specific crops (dry land crops and vegetable crops) and animal products, (2) need for improved nutrient cycling at the farm level, improving soil fertility and reducing soil degradation, (3) need for technologies that increase food, feed and fodder yields, (4) need for access to water for human and animal consumption and off-season, irrigated vegetable gardening, and (5) the need for innovations (institutional & technical) that reduce conflict between different stakeholders around the use of natural resources, (6) availability of seeds and planting material farmer-preferred, improved varieties of annual and perennial crops, and (7) lack of soil and water conservation technologies.

#### 5. Objectives

1. Evaluate the impact of participatory varietal testing in combination with improved crop management options on the demand for and sales of agricultural inputs and seeds of improved varieties of a range of crops (vegetables, field crops and tree seeds/seedlings/grfts).
2. Facilitate access to knowledge and information about markets, options, integrated innovations and inputs for sustainable intensification in order to encourage adoption.
3. Strengthen the capacities of local stakeholders (farmers, extension and research staff...) in evaluating and testing sustainable innovation options associated with farm system components.
4. Test and evaluate the productivity and profitability of combinations of intensification options (improved

- varieties, hybrids, fertilizer application, (bio)pesticides, intercropping etc.) at the field scale
5. Test and evaluate the productivity and profitability of intensified livestock feeding options (stable feeding of small ruminants and dairy cows).
  6. Feedback and discuss results of experimentation to participating farmers in participatory sessions in the villages and to a wider audience through the different platforms
  7. Feedback and discuss results of experimentation to participating farmers in participatory sessions in the villages and to a wider audience through the different platforms
  8. Identify and disseminate suitable cultivars or genotypes and efficient cultivation practices for intensive fruit production of *Ziziphus mauritiana*, *Tamarindus indica*, *Adansonia digitata* and *Vitellaria paradoxa*.
  9. Identify efficient cultivation practices for intensive leafy vegetable production from *Moringa oleifera* and *Adansonia digitata*.
  10. Identify tree species efficient for improving soil fertility, water conservation and fodder production
  11. Estimate relative prevalence of existing mixed cereal/legume-vegetable configurations
  12. Assess productivity and profitability of existing mixed cereal/legume-vegetable configurations
  13. Assess system productivity and profitability gains associated with integrated innovations for cereal-vegetable integration
  14. Collect quality data for parameterization of the farm systems components and the whole farm system
  15. Parameterize models and determine efficiency with different combinations of intensification options

## 6. Work-plan and procedures

<b>Activity 1</b>	Develop profitable and sustainable options to intensify productivity of cereal-legume based crop and crop-livestock systems	
Lead Scientists(s)	Birhanu Zemadim	Institution: ICRISAT
Other Scientist(s)	Eva Weltzien	
Consultant(s)	Ousmane Sanogo	
Student(s)	Mary Ollenburger, Gatien Falconnier	
Location(s)	Koutiala and Bougouni/Yanfolila	

### Procedures

*Sub-activity 1.1: Analyze and report data from cereal-legume-vegetable experiments conducted in 2012 and 2013:* ICRISAT and partners will collect protocols of trials and data collection and reporting in the protocols will be verified at the site and corrected where necessary and possible. Data will be entered and datasets evaluated for quality and quantity before proceeding with statistical analyses. Data will be cleaned and analyzed. Summarized results will be presented in project reports, shared with AR team and presented to farmers and local stakeholders in March in the AR villages. Where possible, a team of AVRDC and ICRISAT will have common trips and meetings presenting and evaluating rainy season cereal, legume and vegetable trials together.

*Sub-activity 1.2: Organize feedback sessions with stakeholders:* Feedback sessions will be organized in each village to present and discuss the results with local partners and farmers. The feedback sessions will consist of four elements, namely (1) presentation and discussion of agronomic results, (2) identification of labor requirements for different treatments and cost-benefit analysis of one or more type of trials, (3) preference ranking of trial types, treatments (options) and (4) short brainstorming for ideas for next years' trials. Data will be synthesized in a short report for Koutiala and Bougouni separately. If possible, these types of analyses will be performed for both the field crop and the vegetable crop trials to create a database of labor requirements for different crops. Farmer preferred varieties of cereals, grain legumes and vegetables will be identified and plans made to make seeds available for sale through the partners in the R4D platforms.

*Sub-activity 1.3: Plan and perform trials on integrated intensification options for cereals and legumes:* Planning workshops will be held with participating farmers in each village to build on the results from the feedback sessions and develop a plan for next years' activities. A maximum of five types of trials per crop type per district will be planned with a minimum of four farmers (replicates) per village. Type of trials and treatments for each type of trial will depend on previous results and farmers' input. We aim to Implement 6 types of intensification trials in Koutiala where the cereals (sorghum, maize) and legumes (groundnut and cowpea) will be intercropped with vegetables - roselle. In Bougouni, trials will be more diverse, as we will be working with cooperatives focusing on organic farming and cooperatives focusing on conventional farming. Preferably, trials are simple 2x2 factor experiments considering farmers as repetitions. For each trial type, we will implement at least 4 repetitions in at least 3 villages (minimum of 12 trials per type) per district.

<b>Activity 2</b>	Determine farmer practices for cereal/legume-vegetable based systems, test integrated innovations and assess productivity and profitability.
Lead Scientists(s)	Albert Rouamba
Other Scientist(s)	Keriba Coulibaly
Student(s)	One to be identified
Location(s)	Koutiala and Bougouni/Yanfolila (Dieba, Flola, Madina, Yorobougoula, Sibiril)

### Procedures

*Sub-activity 2.1: Assess productivity and profitability of integrated innovations for cereal/legume-vegetable cropping systems and identify opportunities for scaling:* Ten farmers (households) per village in each of five villages in each of the Bougouni and Koutiala districts (total of 100) will be selected to participate in testing and diffusion of promising new varieties of the most popular vegetable crops (okra, pepper, tomato and sorrel) in association with the dominant cereal (maize) or legume (groundnut) crops. UDS Two series of trials will be carried out. The first series will test associations of maize with either okra, pepper or tomato in configurations of 100% maize (M), 100% vegetable (V), 75% M + 25% V, 50% M + 50% V, 25% M + 75% V, on plot area basis. In the second series, similar configurations will be used to evaluate the performance of roselle-groundnut associations. Data will be collected on yield and market value of the tested vegetable and maize/legume crops. It is intended that this work will form part of the thesis research of two MSc students to be identified from local universities or agricultural training schools in Mali (or neighboring countries) in consultation with partners.

*Sub-activity 2.2: Test and disseminate promising technologies to intensify vegetable monocropping in cereal-based crop systems in off-season:* As this activity requires off-season infrastructure (fencing and well), only those villages with infrastructure will be concerned (Yorobougoula and Sibirila in Bougouni district and Sirakele, Zansoni and Mpessoba in Koutiala district). Participatory testing and diffusion of promising new vegetable cultivars will be carried out to deliver high value, multiple disease-resistant and nutrient-dense vegetable cultivars in the off-season.

Ten farmers (households) per village in each of five action villages in each of the Bougouni and Koutiala districts (total of 50) will be selected to participate in testing and diffusion of the four most popular vegetable crops (okra, pepper, tomato and sorrel). In each of the five target actions villages, the vegetable crops chosen will be compared across subsets of 10 households per village (depending on crop preference and seed availability) using two planting densities (farmer practice vs. recommended practice).

Data will be collected on yield and market value and utilization (contribution to dietary diversity) of the tested vegetables. It is intended that this work will form part of the thesis research of an MSc student to be identified.

<b>Activity 3</b>	Develop agroforestry options for intensive fruit, vegetable and livestock fodder production
Lead Scientists(s)	Catherine Dembele
Other Scientist(s)	Joachim Binam, Odjouma Samake, Brehima Kone
Student(s)	Traoré Fatoumata
Location(s)	Koutiala and Bougouni/Yanfolila districts

### Procedures

*Sub-activity 3.1: Monitor fruit tree establishment trials established in 2013 for intensive fruit production:* In August 2013, a trial was established on intensive production of fruits from 7 cultivars of *Ziziphus mauritiana* (Ben Gourrion, Gola, ICRAF6, ICRAF8, ICRAF9, Kaithly, and Umran), 3 superior genotypes of *Tamarindus indica* (Niger 309, Thai sucré, Thai gros fruit), 1 genotype of *Adansonia digitata* (Nonokene) and 1 genotype of *Vitellaria paradoxa* (Samanko-ka). The objective was to determine the effect of manure fertilization and farmer's choice of irrigation management on the growth and fruit production of 12 cultivars and genotypes from 4 fruit tree species indigenous to the Sahel. Two replicates of 3 grafted plants for each cultivar or genotype were planted in 5 villages retained for the intervention. These are Mpessoba, Sirakele and Zanzoni in Koutiala district and Sibirila and Yorobougoula in Bougouni district. Plant growth and fruit production will be monitored from 2013 to 2016. Data will be cleaned and analyzed for reporting and publication.

*Sub-activity 3.2: Intensive leafy vegetable production from Adansonia digitata (baobab) and Moringa oleifera:* Baobab and *Moringa* are two tree species producing high value vegetable for human nutrition. The leaves, rich in calcium and good quality protein, are used green or dried as vegetables everywhere in the Sahel zone in

Africa. However, leaves are collected mainly during the rainy season. In order to get fresh leaves year round, intensive method of cultivation is suggested using fertilization and irrigation in each of the 5 target villages. The effect of manure and phosphorus fertilization will be determined. Leaf production will be monitored from 2014 to 2016. Data collected will be analyzed for reporting and publishing. This activity will be linked to nutrition (WP-10: sub-activities 5.2 and 5.3) by raising awareness of the nutritional benefits of *Moringa* and Baobab and testing ways of using the leaves in a variety of recipes.

*Sub-activity 3.3: Improving soil fertility using fodder and fertilizer tree species*

Four fertilizer and fodder tree species trials (*Acacia angustifolia*, *Gliricidia sepium*, *Calliandra calothyrsus* and *Sesbania sesban*) will be planted in at least 5 fields in each of the 5 target villages (Mpressoba, Sirakele and Zanzoni in Koutiala area and Sibirila and Yorobougoula in Bougouni/Yanfolila area). In villages and fields where the contour bund technology (CBT) will be tested (WP-9: sub-activity 4.2), an effort will be made to implement these tests in field with and without CBT. The growth, fodder and wood production of the four species will be measured and the effect of the fodder tree species on soil fertility and soil water dynamics will be monitored. The possibilities of harvesting leaves for livestock feeding trials will be explored, thus linking to Activity 1.4 of this work package. Data collected will be analyzed for reporting.

<b>Activity 4</b>	Estimating efficiency of farm system components and whole farms (economic and agronomic)	
Responsible Scientist(s)	Katrien Descheemaeker	Institution: WUR
Other Scientist(s)	Jeroen Groot	
Student(s)	Mary Ollenburger, Gatien Falconnier	
Location(s)	Koutiala and Bougouni/Yanfolila districts	

**Procedures**

*Sub-activity 4.1: Define and propose a framework for data sharing between Africa RISING partners and Wageningen University:* Wageningen University shares a list of parameters necessary for different types of modeling efforts and analyses that they want to do at the farm and field scale. This list will be reviewed by the scientists involved with on-farm experimentation. Then, a matrix of available and to be collected data (bases) and type of modeling/analyses is created and a plan of action is made to collect complementary data where possible to allow for analyses at farm and field scale. A document is created and reviewed that states the agreed rules for sharing data and information within Africa RISING working groups, including issues related to authorship in case of publication of results.

*Sub-activity 4.2: Parameterize component and whole farm system models and determine trade-offs:* Components of dynamic simulation models (FarmSIM), dynamic farm planning model (FarmSTEPS) will be parameterized. The effects different combinations and scenarios of intensification options on farm efficiency, productivity and landscape ecosystem functioning in different scenarios of socio-economic and biophysical developments will be simulated (ex-ante analysis). Farm scale modeling of NRM and intensification options will be undertaken to analyze trade-offs and synergies between productivity (and profitability), the use of natural resources and provision of ecosystem services (water, soils, carbon and nutrients, biodiversity) within farming systems and between these systems and the surrounding farms and landscape.

**7. Activity schedule**

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Develop profitable and sustainable options to intensify productivity of cereal-legume based crop and crop-livestock systems	x	x	x	x	x	x	x	x	x	x	x	x
2. Develop options for intensification of vegetable production systems		x	x	x	x	x	x	x	x	x	x	x
3. Develop agroforestry options for intensive fruit, vegetable and livestock fodder production		x	x	x	x	x	x	x	x	x	x	x
4. Estimates of farm efficiency through modeling (economic and agronomic)		x	x	x	x	x	x	x	x	x	x	x

## 8. Capacity building

	<i>Male</i>			<i>Female</i>		
	2014	2015	2016	2014	2015	2016
Farmers	100	100		50	50	
Farmers' associations	5	5		5	5	
Extension officers	1	1				
Researchers	2	2		2	2	
Input dealers	2	4	8	1	1	
Policy makers	1	5				
Development partners	3	3		2	2	

## 9. Student training

	<i>Male</i>			<i>Female</i>		
	2014	2015	2016	2014	2015	2016
BSc	2	2		2	2	
MSc students	1	1	1	1	1	1
PhD students	1	1	1	2	2	2
Interns/non-degree	1	1	1	1	1	1

## 10. Communication and dissemination

	2014	2015	2016
Workshops/meetings	2	2	2
Field days	10	10	10
Conference papers	2	2	2
Journal article	0	2	2
Others (video, sorghum thinning)	1		

## 11. How are gender issues addressed?

The activities and crops aim to cater for both men (especially cereal crops) and women (especially groundnut, in and off-season vegetables), while field days and planning meetings will include women as much as possible. Gender will further be addressed through our local partners (MOBIOM, AMASSA and AMEDD) who closely collaborate with women and mixed cooperatives, that aim to market crop, tree and livestock products and access inputs and credit.

## 12. Deliverables

- 1 Report on cereal-legume trials – yearly interim reports and final report in 2016
- 3 List of farmers and the type of trials to be conducted in 2014, 2015 and 2016 – June each year
- 5 Reports on training on trial establishment and evaluation – interim reports yearly in March
- 6 Database for agronomic and economic performance and labor requirements for different SI options and combinations
- 7 Report on fruit trees, fodder/fertilizer trees and leafy vegetables from baobab and *Moringa* - interim reports 2014, 2015 and 2016
- 8 Report on integrated cereal/legume-vegetable systems, vegetables for off-season production – interim reports 2014, 2015 and 2016
- 9 Matrix of data (bases) and possible modeling efforts and analyses available – December 2014
- 10 Parameterized models for farm system components (fields, animals etc.) and different farm types in the study sites available –December 2014
- 11 Ex-ante analysis of the effect of various intensification options under different future scenarios – December 2015
- 11 Report on farm efficiency, profitability and trade-offs, and the effect of combinations of intensification options for different farm types in the study sites available – interim reports yearly in March

## 13. Expected outputs

- Integrated options to intensify and increase efficiency of crop—livestock, vegetable and tree components of farming systems
- Information about market prices of livestock, crop and tree products on a monthly basis and basic household characteristics in Africa RISING villages on a yearly basis

- Estimates of farm efficiency (economic and agronomic) using information from other outputs mentioned above

#### 14. Expected outcomes

- More farmers integrate vegetables and legumes into their cereal cropping systems.
- Farmers adjust their vegetable cropping patterns to increase the number of plants per unit area

#### 15. Potential impact of outcome

<i>Item</i>	<i>Impact</i>
Household crop production	Higher land, labor and/or fertilizer use efficiency (medium term)
Household livestock production	Higher productivity of livestock, such as small ruminants and dairy cows. Potentially, higher oxen productivity for ploughing and weeding activities (medium term)
Environment (on-farm soil properties)	Potentially less degradation of soils, higher organic matter contents and less soil and nutrient losses. Not measureable in project period, but possible to model (long term)
Household income	Higher profits and returns to investment with integrated innovations for SI at farm component and whole farm level (long term)
Household nutrition (women and children)	More diversity and higher levels of legume and vegetable crop production may lead to increased consumption and processing into household meals, potentially reducing malnutrition (long term)

#### 16. 2014 Budget (US\$)

		Partners						
		ICRISAT	AVRDC	ICRAF	IER	AMASSA	MOBIOM	WUR
Activity								
1	Personnel	20000				3000	3000	
	Services	0			2000	1000	2000	
	Supplies	10000				3000	2000	
	Travel	10000			4000	2000	5000	
	Total	<b>40000</b>			<b>6000</b>	<b>9000</b>	<b>12000</b>	
Activity								
2	Personnel		40000			3500	3500	
	Services		21000			2000	2000	
	Supplies		25000			2500	2500	
	Travel		13000			2000	2000	
	Total		<b>99000</b>			<b>10000</b>	<b>10000</b>	
Activity								
3	Personnel			15000		2000	2000	
	Services			10000		1000	1000	
	Supplies			10000		2000	2000	
	Travel			15000		2000	2000	
	Total			<b>50000</b>		<b>7000</b>	<b>7000</b>	
Activity								
4	Personnel							
	Services							
	Supplies							5000
	Travel							
	Total							<b>5000</b>
<b>Grand total</b>		<b>40000</b>	<b>99000</b>	<b>50000</b>	<b>6000</b>	<b>26000</b>	<b>29000</b>	<b>5000</b>

## Work-package WP-6

### 1. Title: Intensifying livestock and poultry production in Ghana and Mali

#### 2. Research team

<i>Name</i>	<i>Institution</i>	<i>Degree</i>	<i>Research interest</i>	<i>Role</i>
Augustine Ayantunde	ILRI	PhD	Feeds, nutrient management	Over-see ILRI's activities, PI
Acho Okike	ILRI	PhD	Value chain development	Livestock value chain
Tunde Amole	ILRI	PhD	Agricultural economics	Feed assessment
Franklin Avonyo	ARI	PhD	Feeds, animal husbandry	Small ruminant production
Solomon Konlan	ARI	MSc	Feeds, animal husbandry	PhD student - nutrient flows
Naaminong Karbo	ARI	PhD	Animal husbandry	Coordinate ARI activities
Birhanu Zemadim	ICRISAT	PhD	Watershed management	Deputy PI
Mary Ollenburger	WUR	MSc	Farm systems research	PhD student - farming systems
Asamoah Larbi	IITA	PhD	Forage agronomy, nutrition	Coordination, Deputy PI
Ousmane Sanogo	IER	PhD	Farming systems	Socio-economic analysis
Gatien Falconnier	WUR	MSc	Farming systems	PhD student - farming systems
Roland Kanlisi	HI	MSc	Veterinary epidemiology	HI project oversight
Ebenezer Ghamli	HI	DVM	Veterinary medicine	Animal health
Emma Nartey	HI	BSc	Animal health	Animal production
D.B. Okai	KNUST	PhD	Animal nutrition-pigs	Lead Activity 4
Michael Boateng	KNUST	PhD	Monogastric nutrition	Graduate supervision
Herbert K. Dei	UDS	PhD	Animal nutrition-poultry	Poultry production
Ben Alenyorege	UDS	MSc	Animal production-pigs	Pig production
Shaibu Bedi	IITA	BSc	Agricultural economics	Monitoring trials
Terry Ansah	UDS	MSc	Animal production	Pasture science

#### 3. Summary

The work-package aims at improving livestock (cattle, sheep, goat, pig) and poultry production. The activities on small ruminant production include testing and dissemination of feed and health interventions at community level to improve production, monitoring of the nutrient flows in the systems, and building capacity of partners in better management practices. The rural poultry and pigs component focuses on developing and disseminating improved technologies to intensify and improve rural pig and poultry production to improve food security and livelihoods.

#### 4. Research problem and justification

Livestock (cattle, sheep, goats, pigs,) and rural poultry play an important role in food production. They are kept under extensive or semi-intensive management with limited input in feeding, housing, breeding and health care management resulting in low production and high mortality rates from pest and diseases are high. Livestock keepers have limited access to markets and market information. Adding value to livestock products through processing to capture niche markets and improve profit margins is limited. There is need to empower rural livestock keepers to intensify and diversify the traditional low-input systems to increase meat and milk production for home consumption and sale.

Ruminant livestock (cattle, sheep and goat) are of high importance in these three regions (northern, upper east and upper west) as they account for approximately 75% of cattle, 37% of sheep and 42% of goats of the national population. Effective integration of ruminant livestock with crops (cereals and legumes) is critical to the whole farm productivity as well as efficient nutrient management in the mixed systems. The key integration pathways of crop and livestock systems are through manure for soil fertility improvement, crop residues as animal feed, and animal traction for cropping activities. Various forms of crop-livestock interactions are developing in northern Ghana and are at different stages of development. It ranged from "opportunistic" collection of animal manure from the range for home use to fairly systematic, planned nutrient cycling practices involving manure, urine, crop residues, compost, etc.

Considering whole farm productivity, profitability and sustainability, strategies to intensify cattle, sheep and goat production should be in the context of effective integration with crops and targeted use of external inputs. This will require combinations of technologies such as improved management of fallow/grazing lands, livestock and poultry breeds and management practices that will contribute to higher livestock productivity, improved household food security and income.



## 5. Objectives

- 1 Test feed and health interventions for improved small ruminant production
- 2 Evaluate the effects of seasonal variations in nutrients offered on animal performances, and identify strategies to enhance better nutrient management
- 3 Assess cost and benefit of the feed and health interventions at household level
- 4 Explore possibilities of fattening lambs to capture niche markets in Mali
- 5 Publish a booklet on rural poultry and pig farming systems in Ghana
- 6 Evaluate/disseminate feeding, health, breeding and housing options to intensify rural pig production
- 7 Evaluate/disseminate feeding, health, breeding and housing options to intensify rural poultry production
- 8 Strengthen capacity of farmers, research and extension staff and students in poultry and pig production

## 6. Work-plan and procedures

<b>Activity 1</b>	Feed and health interventions for improved small ruminant production	
Lead Scientist(s)	Augustine Ayantunde, Acho Okike	Institution: ILRI
Other Scientist(s)	Franklin Avornyo, Tunde Amole	
Student(s)	Solomon Konlan, Emmanuel Gyakah, Joseph Clottey and Mohammed Shaibu	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

*Sub-activity 1.1: Feed and health interventions for improved small ruminant production in Ghana:* It has been demonstrated that simple interventions involving disease control, improved nutrition and better management lead to marked positive effects on small ruminant performance and productivity. Building on activity conducted in 2012 and 2013, feed and health interventions will be carried out in 9 communities involving 3 treatments (Treatment 1 = health intervention: vaccination against PPR and Pasteurellosis and deworming using Ivermectin; Treatment 2= health intervention as above and supplementary feeding of balanced rations) and a control (Treatment 3 = no health and no feed intervention). One village will be selected in each region for each treatment making three villages per region. All small ruminants (sheep and goats) in the six villages (2 villages per region) with health interventions will be vaccinated against PPR and pasteurellosis, and will be dewormed. The feed interventions will be applied to 10 households in one village per region. In all the nine villages to be selected for the study, 10 households will be selected for monitoring of their flocks. All sheep and goats in these households will be ear-tagged and weighed monthly. Manure production will be collected and weighed monthly. A research assistant will be based in each village for the monitoring of the flock dynamics of the selected households in terms of entries (birth, purchase, animal received as gift or on loan) and exits (death, sales, and slaughter for household consumption, animal given out as gift or loan). Cost-benefit analyses will be conducted to assess the profitability of feed and health interventions. The 3 treatments explained above will be applied at a village level because of the nature of the treatments (in particular the health intervention one). The villages in the same region (3) will be considered as a 'block' given that they are close enough and matched enough (on agroecological and socio-economic profile). The villages will be RANDOMLY allocated to one of the 3 treatments. Mixed effect models will be used for ANOVA for any response variable with Region effect (2 degrees of freedom), Treatment effect (2 d.f.) and 4 d.f. for the residual and each treatment has 3 replications / villages.

*Sub-activity 1.2: Building capacity of smallholders in small ruminant production in Ghana:* Workshops will be organized to train farmers on many aspects of small ruminant production including disease control, feed formulation, better animal management practices and marketing. For building the capacity of the local communities in disease control, key members of livestock farmers' association will be trained in each community by the veterinarians from Ministry of Food and Agriculture in diagnosis of common small ruminant diseases, record keeping and in providing preliminary treatments subject to the national law for the operations of Community-based Animal Health Workers. The community members to be trained will also be responsible for providing timely situation report to the veterinary services at the district level.

*Sub-activity 1.3: Nutrient flows in small ruminant production systems in Ghana:* Quantifying the nutrient use in smallholder livestock production systems is essential to balancing nutrients supplied in feeds to animals' requirements, leading to improved livestock production, and consequently whole farm productivity and economic profitability. Also this is important to identify options or strategies for better nutrient management

in the systems thereby reducing waste and loss. Eight out of the 20 households to be selected under sub-activity 1.1 will be selected in the three communities in each region (Upper West, Upper East and Northern regions) on the criteria of integration of crop and livestock systems, and willingness to participate in long term study. These households will be monitored over 24 months to address seasonal variations in nutrient use. Feeding practices of the selected household will be monitored as well as manure production of the household flock. Feed and faecal samples will be collected for laboratory analysis to determine nutrient inflows and outflows in the systems. This activity will be carried out along with activity on improving small ruminant production.

<b>Activity 2</b>	Plan and perform trials on integrated intensification options for livestock feeding in Mali	
Lead Scientists(s)	Birhanu Zemadim	Institution: ICRISAT
Consultant(s)	Ousmane Sanogo	
Student(s)	Mary Ollenburger, Gatien Falconnier	
Location(s)	Koutiala and Bougouni/Yanfolila	

### Procedures

Planning workshops will be held with participating farmers in the villages of Dieba, Sibirila and Yorobougoula, in Bougouni and Yanfolila districts. The workshops will build on the results from sheep strategic feeding trials for sales of rams near the Muslim “Feast of the Sacrifice” called Tabaski, in 2013 in Yorobougoula and fodder production plots and fodder storage activities in 2013. A maximum of 10 trial repetitions (farmers) per village will be planned with three treatments (sheep) per farmer. Type of trials and treatments will depend on previous results, scientists and farmers’ input. Fodder previously produced; stored and currently available are cowpea and groundnut haulms, maize bran and stalks and pasture grasses.

All animals will receive veterinary treatments before and during the trials. The trials will be initiated in the first quarter of 2014 and end in the second quarter of 2014. Animal weights will be monitored from the start on a bi-weekly basis and individual sheep sales prices after the feeding trials will be determined. Data will be entered and analyzed by the end of the second quarter of 2014. A feedback session will be held around August-September to determine profitability of strategic feeding treatments and plan for future activities

<b>Activity 3</b>	Test and disseminate management packages to intensify rural poultry production	
Lead Scientist(s)	Herbert Dei, Asamoah Larbi	Institution: UDS, IITA
Other Scientist(s)	I Mohammed, Michael Boateng	
Student(s)	Safo-Kantaka G, Daniel Apalibe	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

*Sub-activity 3.1: Publish survey report into a booklet:* A survey of rural poultry production systems in the intervention communities was completed in 2013. The survey report will be edited and published into a booklet.

*Sub-activity 3.2: Develop, evaluate and disseminate improved technologies to intensify poultry production:* The survey in 2013 identified lack of enabling institutions and policies, poor market access, lack of improved breeding, inappropriate husbandry (housing, feeding, breeding and health care) practices, as well as lack of information/knowledge as key constraints to rural poultry production. In 2014, farmer participatory research will be conducted to test a combination of housing, feeding and health packages to address the constraints. The exact packages to be tested will be determined from consultations with farmers. Most likely combinations will be to test the traditional systems of management (control) and improved management (housing, health-care and feeding) using a randomized complete block design with districts as blocks. . Data to be collected will include matured live-weight, duration to maturity, mortality, duration of brooding, number of eggs, production costs, income, quantity of manure and profit over a period of 40 days. Trials will be conducted on both domestic chicken and guinea fowls.

*Sub-activity 3.3: Supervision of graduate students:* Two graduate students (1 MSc and 1 PhD) will be supervised to use the activities under sub-activity 3.2 for their dissertation research.

<b>Activity 4</b>	Develop, test and disseminate technologies to intensify rural pig production	
Lead Scientist(s)	Michael Boateng, Asamoah Larbi	Institution: KNUST, IITA
Other Scientist(s)	Ben Alenyorege, I Mohammed	
Consultant(s)	Daniel Okine	
Student(s)	Raphael Ayizanga, Amponsa Bright, Mary Awuni	

## Procedures

*Sub-activity 4.1: Publish survey report into a booklet:* A survey of rural pig production in 2013 identified lack of enabling institutions and policies, poor market access, lack of improved breeding, inappropriate husbandry (housing, feeding, breeding and health care) practices as key constraints to rural pig production.

*Sub-activity 4.2: Develop, evaluate and disseminate technologies to intensify rural pig production:* In 2014, farmer participatory approaches will be used to develop, evaluate and disseminate a combination of housing, feeding, breeding and health care options to improve and intensify rural pig production. These will include trials on: comparison of extensive versus intensive management; effect of supplementation in performance of grower and finisher pigs under the free range management system; a survey to document green forage species fed to pigs, and the performance of growing pigs supplemented with different levels of concentrates; development and testing of breeding strategies to reduce in breeding, meet processing and linking farmers to markets. In all trials, feed intake, body weight gain, feed conversion efficiency, mature live-weight, mortality rate, production costs and net profit will be recorded. The impact of the improved technologies on household income will be assessed.

*Sub-activity 4.3: Train graduate students:* One PhD and two MSc students will be supervised to use the farmer participatory research activities in sub-activity 4.2 for their dissertation research.

## 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Publish a booklet on pigs/poultry		x	x	x	x	x						
2. Health and nutrition for sheep/goats	x	x	x	x	x	x	x	x	x	x		
3. Improving poultry production	x	x	x	x	x	x	x	x	x	x		
4. Improving pig production	x	x	x	x	x	x	x	x	x	x		

## 8. Capacity building:

	Male			Female		
	2014	2015	2016	2014	2015	2016
Farmers	900	1200	1500	400	800	800
Farmers' associations	4	6	10	2	5	6
Extension officers	3	5	7	4	5	8
Researchers	2	4	6	2	4	4
Input dealers	2	3	5	1	2	2
Policy makers	2	3	4	1	2	3
Development partners	2	2	3	1	0	0

## 9. Student training

	Male			Female		
	2014	2015	2016	2014	2015	2016
BSc	3	5	6	2	4	4
MSc students	3	3	3	1	2	2
PhD students	2	3	2	0	0	0
Interns/non-degree	2	3	3	2	4	4

## 10. Communication and dissemination

	2014	2015	2016
Workshops/meetings	Mar-Jun	Mar-Jun	Mar-Jun

Field days	Sep-Oct	Sep-Oct	Sep-Oct
Conference papers	May-Jul	May-Jul	May-Jul
Journal article	Mar-May	Sep-Nov	Sep-Nov
Others (Exchange visits)	Sep-Nov	Sep-Nov	Sep-Nov

### 11. How are gender issues addressed?

Small ruminants and poultry are largely raised by women. Focusing on improvement of small ruminant production will therefore directly contribute to improved household food security and income. The training workshops to strengthen the development of key livestock value chains will include women actors. Women and youth will be targeted for sensitization and awareness creation on dairy goat milk production and utilization. Gender awareness and gender equity will be created in all the project communities. Gender equity issues will be mainstreamed in all project meetings. Barriers-to-participation will be reduced by offering gender sensitive interventions and the use of appropriate styles and language in all capacity building activities. Women interest groups (WIGs) will be promoted and linked to credit.

### 12. Deliverables

- 1 Report on on-farm feed/health interventions for improved small ruminants – December 2015
- 2 Training workshop on improved small ruminant practices in each region – December 2015
- 3 Interim report on nutrient flows in small ruminant production systems – January 2015
- 4 A booklet on survey of rural poultry and pig farming in Ghana – December 2014
- 5 An interim report on options to intensify poultry and pig production – September 2014
- 6 At least 3 improved pig and poultry management options tested with farmers – March 2015
- 7 Report on strategic lamb fattening in Mali – December 2014

### 13. Expected outputs

- Options for improved sheep and goat production developed and tested – December 2014
- Options for improved pig and poultry production developed and tested – December 2016
- At least 4 graduate dissertations completed – June 2016

### 14. Expected outcomes

- Households keep their livestock under improved husbandry conditions (feeding, housing, health care)
- Households have improved manure management
- Farmers are adopting lamb fattening to capture niche markets

### 15. Potential impact of outcome

<i>Item</i>	<i>Impact</i>
Household crop production	Crop yields will increase from more and better quality manure from better fed livestock
Household livestock production	Reduction in mortality rates; meat, milk and egg output increased from better housing, feeding, breeding and health care; more off take to meet household needs
Environment (on-farm soil properties)	Reduced degradation of soil, water and plant resources through better management of fallow and grazing lands
Household income	Income will increase through sale of more livestock products
Household nutrition (women and children)	Increased nutrition through intake of more and diversified livestock products

**16. 2014 Budgets (US\$)**

	Budget Line	ILRI	ICRISAT	UDS	KNUST	IITA
Activity 1	Personnel	74000				
	Services	18000				
	Supplies	21000				
	Travel	16000				
	<b>Total</b>	<b>129000</b>				
Activity 2	Personnel		10000			
	Services		2000			
	Supplies		10000			
	Travel		3000			
	<b>Total</b>		<b>25000</b>			
Activity 3	Personnel			6000		6000
	Services			3000		3000
	Supplies			7000		7000
	Travel			4000		4000
	<b>Total</b>			<b>20,000</b>		<b>20,000</b>
Activity 4	Personnel				6000	6000
	Services				3000	5000
	Supplies				7000	5000
	Travel				4000	4000
	<b>Total</b>				<b>20,000</b>	<b>20,000</b>
<b>Total</b>		<b>129000</b>	<b>25000</b>	<b>20000</b>	<b>20000</b>	<b>40000</b>

## Work-package WP-7

### 1. Title: Raising and sustaining productivity in integrated crop-livestock systems in northern Ghana

#### 2. Research team

<i>Name</i>	<i>Institution</i>	<i>Degree</i>	<i>Research interest</i>	<i>Role</i>
Asamoah Larbi	IITA	PhD	Crop-livestock, feeds	Principal Investigator (PI).
Saaka Buah	SARI	PhD	Plant nutrition, agronomy	Deputy PI.
Bekele Kuto	IITA	PhD	Agricultural economist	Economic analysis
Vicent Avornyo	UDS	PhD	Soil science	Soil fertility management
Richard Opoku	UDS	PhD	Plant pathology	Integrated pest management
Dominic Sobreh	IITA	MPh	Agronomy-vegetables	Field layout, data collection
Daniel Akakpo	IITA	MPh	Agronomy	Field layout, data collection
Shaibu Bedi	IITA	BSc	Agricultural economics	Surveys, monitoring, database
Tim Ellis	IWMI	PhD	Agric. water management	Lead, IWMI activities
Roger Kanton	SARI	PhD	Agronomy	Agronomy, UER
Francis Kusi	SARI	MPh	Entomology	Integrated pest management
Peter Asongre	SARI	MPh	Millet breeding	Millet agronomy
Issah Suguri	SARI	MPh	Post-harvest science	Post-harvest management
Julius Yirzagla	SARI	MPh	Systems agronomy	Cereal-legume cropping systems
Terry Ansah	UDS	MSc	Animal production	Pasture science

#### 3. Summary

This work-package employs adaptive, community-based, participatory approaches to identify, evaluate, demonstrate and disseminate knowledge and good practices to better integrate the crop and livestock enterprises in the smallholder mixed farming systems. The options being explored include: integration of livestock into fallow land management and tree/fruit tree plantations, cereal-legume strip cropping to increase food and feed production, corralling of livestock on crop/fallow lands for manure, cover crops and living mulch and identification high-yielding and better quality food feed crops.

#### 4. Research problem and justification

Small-scale crop-livestock systems are the most predominant system in northern Ghana. Farmers grow cereals (e.g., maize, rice, millet and sorghum), legumes (e.g.: groundnut, cowpea, soybean, Bambara, pigeon pea) and vegetables; and raise livestock (cattle, sheeps, goats, pigs) and poultry under extensive and semi-intensive systems. The livestock provide meat and milk for food, manure for crop production, cash, power for land cultivation and transport. Fallow land grazing and crop residues are the main feed resources for the livestock. Due to high human and livestock populations, fallow lands are overgrazed leading to degradation of the land, soil and vegetation resources. Total productivity of the integrated crop-livestock systems is generally low, partly due to weak integration of the crop and livestock enterprises.

Strategies are needed to intensify and diversify the crop and livestock enterprises for better integration. Such strategies include: identification of high-yielding and better quality food-feed crops, the use of living mulch and cover crops for food, feed and soil fertility management, integration of livestock into plantation and fruit trees, adjustment of cropping systems to optimize food and feed production, and fallow land management to improve crop and livestock product outputs. Quantitative data on such strategies are limited in Ghana, especially in the three northern regions. The purpose of this work-package is to develop, test and disseminate option to strengthen the link between the crop and livestock enterprises in the smallholder crop-cereal-livestock farming systems in northern Ghana.

#### 5. Specific objectives or research questions

- 1 Identify fallow land management constraints and opportunities in target communities
- 2 Document policies and institutions on fallow land management
- 3 Characterize and conserve fallow land biodiversity
- 4 Test and disseminate options to increase crop and livestock outputs from fallow lands
- 5 Determine forage resources under plantation crops
- 6 Study stocking rate effects on sheep and forage productivity and soil under mango plantation
- 7 Evaluate the biological and economic potential of integrating sheep into mango plantations
- 8 Evaluate and disseminate sorghum/millet-cowpea strip cropping for integrated crop-livestock production
- 9 Test and disseminate agronomic strategies to reduce cropping season feed gap
- 10 Evaluate and disseminate grain legumes as living mulch for integrated crop-livestock production

- 11 Identify high-yield and better quality cereal and legume crop genotypes for food and feed
- 12 Organize short-courses on experimental design and data analysis and integrated crop-livestock systems
- 13 Organize a short-course on 'Experimental Design and Data Analysis' for young researchers
- 14 Organize a short-course on 'Integrated Crop-Livestock Production Systems'

## 6. Work-plan and procedures

<b>Activity 1</b>	Integrate livestock into fallow lands to increase and sustain productivity	
Lead Scientist(s)	Asamoah Larbi, Terry Ansah, Bekele Kotu	Institution: IITA, UDS
Other Scientist(s)	Abdul Nurudeen, Roland Kanlisi, Emmanuel Nartey, Ebenezer Ghamli	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

*Sub-activity 1.1: Identify fallow land management constraints and opportunities and establish community-based fallow land management committee (FLMC):* Organize focal group discussions with farmers in the target communities to identify key constraints and opportunities for managing fallow land for livestock production. Conduct multiple-site survey of production systems to complement and fill information gaps. Document indigenous knowledge on fallow land-livestock systems. Organize workshops to discuss baseline information and identify the social, institutional and economic determinants of unsustainable use of fallow lands, and develop feasible options for improved use and management of these resources. Organize workshops to discuss results and identify socio-economic and bio-physical interventions, research topics, and roles and responsibilities of all stakeholders. A multi-institutional and gender-sensitive FLMC of 5 (4 men and one woman) will be established and charged with the development of a community fallow land livestock development plans. The plans will be discussed and approved.

*Sub-activity 1.2: Document policies and institutions on fallow land management:* Document current policies and institution/institutional arrangement governing control and access to fallow land resources. Analyze current policies that influence livestock mobility and fallow land utilization. Develop technical, institutional and policy options, integrated into a natural fallow land management scheme that would raise and sustain the production system.

*Sub-activity 1.3: Characterize and conserve fallow land biodiversity:* Permanent monitoring sites will be established. Indigenous knowledge will be used to identify fallow land plant species essential for rehabilitation, livestock nutrition and health, and fuel wood production. Priority will be given to: key native species that are tolerant to drought, salinity and grazing; ethno-medicinal species, and under-utilized and dual-purpose species. The species will be collected and preserved. Seeds of the essential species will be collected and multiplied. Their biomass and seed production potential will be evaluated. Annual and seasonal net primary production and nutritive value will be quantified.

*Sub-activity 1.4: Community actions to test and disseminate interventions to improve fallow land productivity and conserve the natural resource base:* Under the leadership of the FLMC, community-based workshops will be organized with farmers to discuss the socio-economic and environmental impact of fallow land degradation, to raise awareness and promote associative and community-based measures to restore overgrazed fallow land. Techniques for rehabilitation of degraded fallow land will be tested with farmers' participation. This will include: technologies for mass seed production of target species at the community-level, water harvesting for crop and livestock production, reseeding using indigenous and introduced prominent species, establishment of leguminous shrub/tree plantations fodder banks, direct seeding, weed/brush control, grazing schemes to improve fallow land productivity, e.g., resting. Fallow land exclusion areas will be established. Protected sites will be compared with those that are continuously grazed. Total plant cover, composition of perennial species, biomass production and species richness will be monitored. Strategies to improve crop production from fallow lands will be explored. This will include improved fallow and corralling of livestock on fallow lands for manure.

<b>Activity 2</b>	Integrate livestock under tree plantations for income diversification	
Lead Scientist(s)	Asamoah Larbi, Terry Ansah	Institution: IITA, UDS
Other Scientist(s)	Bekele Kotu, Roland Kanlisi, Emmanuel Nartey	
Partner(s)	UDS, IITA, HI	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo,	

### Procedures

Silvo-pasture, the integration of trees, forage plants, and livestock (cattle, sheep, goats, etc) is an intensively managed systems, provides means of diversifying on-farm income by providing a short-term income from grazing, while trees are grown for longer-term profit. Mango plantations, which are essentially tree rows with vegetated alleys, have the potential to be managed as silvopastures thereby increasing farm diversification, sustainability, production and profitability. They can graze freely underneath relatively mature tree plantations grown for fruit and wood. This scheme allows fruits and meat from grazing sheep to be produced at the same time. The sheep keep the underneath vegetation down, saving labor costs in cleaning the plantation, and making it easier to collect the fallen fruits. The sheep dung over the plantation serves as an excellent organic fertilizer.

Three treatments: 1) control (no-grazing), 2) grazing at low stocking rate and 3) grazing at high stocking rate will be super-imposed on an existing mango plantation. A randomized block design with three replications will be used. Weaned rams will be purchased and quarantined for two weeks during which they will be vaccinated, dewormed, and given antibiotics. Initial weight of the animals will be after which they will be randomly assigned to the treatments in mid-July.

Undergrowth biomass and composition, soil chemical and physical properties before grazing. Animals will be weighed weekly during the grazing period. Biomass and composition of the undergrowth will be estimated every two weeks. Samples of the forage on offer and grab fecal samples will be analyzed for crude protein, acid and neutral detergent fibre, in vitro dry matter digestibility. Grazing will be stopped when 50% of the sheep start losing weight. Cost-benefit analysis will be performed.

<b>Activity 3</b>	Farmer participatory evaluation of sorghum/millet-cowpea crop-livestock systems	
Lead Scientist(s)	Asamoah Larbi, Terry Ansah	Institution: IITA, UDS
Other Scientist(s)	Desire Dickson, Terry Ansah, Bekele Kotu, Roland Kanlisi, Emmanuel Nartey, Peter Asongre	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Previous research by IITA and ILRI showed that one of the best-bet options for integrating crop and livestock production in the dry savannahs is an improved strip cropping system involving 2 rows of densely planted improved sorghum: to 4 rows of densely planted improved cowpea. A basal dose of 100kg/ha of NPK (15:15:15) is given followed by a selective application of 20kg/ha N only on sorghum rows and two sprays of insecticide only on cowpea. Since the improved system involved 2/3 area under cowpea and 1/3 under sorghum, not only the soil fertility is improved but there is substantial reduction in the incidence of *Striga hermonthica*, which parasites sorghum and other cereal. This technology has not been widely scaled out in Ghana. Also, the 2 rows of sorghum to 4 rows of cowpea technology have not been compared with 2 rows of sorghum and 2 rows of cowpea. Further, information is limited on using early millet instead of sorghum as the cereal crop. An on-farm trial will be conducted for sorghum and millet-based systems with the following treatment combination:

#### *Sub-activity 3.1: Evaluation of sorghum-cowpea strip cropping for integrated crop-livestock production:*

1. 2 rows of sorghum to 4 rows of cowpea – without livestock (residue retained as mulch)
2. 2 rows of sorghum to 2 rows of cowpea – without livestock (residue retained as mulch)
3. 2 row of sorghum to 4 rows of cowpea – plus livestock (residue removed and stored for dry season feeding)
4. 2 rows of sorghum to 2 rows of cowpea – plus livestock (residue removed and stored for dry season feeding)

#### *Sub-activity 3.2: Evaluation of early millet-cowpea strip cropping for integrated crop-livestock production:*

1. 2 rows of early millet to 4 rows of cowpea – without livestock (residue retained as mulch)
2. 2 rows of early millet to 2 rows of cowpea – without livestock (residue retained as mulch)
3. 2 row of early millet to 4 rows of cowpea – plus livestock (residue removed and stored for dry season feeding)



4. 2 rows of early millet to 2 rows of cowpea – plus livestock (residue removed and stored for dry season feeding)

The trials will be conducted for at least two seasons. Each sub-activity will be implemented with 10-20 households. For treatment with livestock, residues will be collected after harvesting and stored for dry season feeding of sheep and goats. Both biological (grain and fodder yields, weed diversity and biomass, soil chemical and physical properties, livestock weight gain and manure outputs) and socio-economic data will be collected. Impact of the technologies on household food production and income will be assessed.

<b>Activity 4</b>	Raising/sustaining productivity of integrated crop-livestock systems: Leaf stripping	
Lead Scientist(s)	Asamoah Larbi, Saaka Buah, Bekele Kotu	Institution: IITA, SARI
Other Scientist(s)	Daniel Akakpo, Dominc Sobreh, Shaibu Mellon, Mumuni Abdulaih, Francis Kusi, James Kombiok, Issah Sugri, Peter Asongre, Roger Kanton, Julius Yilzagla	
Student(s)	Abdul Rhaman Nurudeen	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

In the small-scale crop-livestock systems, livestock (cattle, sheeps, goats, and pigs) are either tethered or penned to prevent crop destruction during the cropping season. The penned or tethered animals are given little or no feed supplements leading to weight loss and high mortalities. The objective is to explore the possibilities of adjusting the cropping pattern to produce feed from thinning and leaf stripping.

A split-plot design replicated in 3-4 communities per region will be used. Maize planting density (5, 10 and 15 plants/m<sup>2</sup>) are main-plots, while no leaf-stripping, leaf-stripping after tassel ling and leaf-stripping after cob formation are sub-plots. The stripped leaves will be used as supplements to tethered piglets and kids. Cost-benefit analysis will be performed. Growth and yield of grain and stover; weed diversity and biomass; quality of the fodder; and weekly live-weight changes in the growing animals fed the fodder will be monitored.

<b>Activity 5</b>	Options to intensify/diversify the crops and cereal-legume cropping: Living mulch	
Lead Scientist(s)	Asamoah Larbi, Saaka Buah, Bekele Kotu	Institution: IITA, SARI
Other Scientist(s)	Daniel Akakpo, Dominc Sobreh, Shaibu Mellon, Peter Asongre, Roger Kanton	
Student(s)	Abdul Rahman Nurudeen	
Locations(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

*Sub-activity 5.1: Time of sowing cowpea living mulch on maize grain yield and soil properties:* A split-split plot design replicated in 3-4 communities per region will be used to investigate the influence of land preparation method, sowing date of a grain legume (cowpea) live-mulch, and maize maturity type. Main-plots are land preparation method (no-till-kill vegetation with contact herbicide, hand-hoeing and plough), sub-plots are cowpea sowing date (15 days prior to maize sowing, simultaneously with maize, and 15 days after sowing maize), and sub-sub-plots are maize maturity types (extra-early, early and medium). Growth and grain yield of maize, cowpea grain and biomass yield, weed biomass, surface run-off, soil physical (infiltration rate, porosity, temperature, bulk density), chemical (N, P, K), and biological (micro and macro fauna) properties will be recorded. Separate trials with the same treatments and procedure will be implemented using soybean and groundnut as legumes.

*Sub-activity 5.2: Planting density of cowpea living mulch on maize grain yield and soil properties:* A split-split plot design replicated in 3-4 communities per region will be used to investigate the influence of land preparation method, grain legume live-mulch sow density, date, and maize planting density on grain yield and the soil and water resources. Main-plots are land preparation method (no-till-kill vegetation with contact herbicide, hand-hoeing and plough), sub-plots are cowpea sowing density (0, 15 and 30 plants/m<sup>2</sup>) are maize planting density (recommended, higher rate). Growth and grain yield of maize, cowpea grain and biomass yield, weed biomass, surface run-off; soil physical (infiltration rate, porosity, temperature, bulk density), chemical (N, P, K), and biological (micro and macro fauna) properties will be recorded. Separate trials with the same treatments and procedure will be implemented using soybean and groundnut as legumes.

*Sub-activity 5.3: Time of sowing groundnut living mulch on maize grain yield and soil properties:* The

treatments and procedures are the same as those described for sub-activity 5.1, with groundnut as the legume.

*Sub-activity 5.4: Planting density of groundnut living mulch on maize grain yield and soil properties:* The treatments and procedures are the same as those described for sub-activity 5.2, with groundnut as the legume.

*Sub-activity 5.5: Time of sowing cowpea living mulch on early millet grain yield and soil properties:* The treatments and procedures are the same as those described for sub-activity 5.1, with early millet as the cereal.

*Sub-activity 5.6: Planting density of cowpea living mulch on early millet grain yield and soil properties:* The treatments and procedures are the same as those described for sub-activity 5.2, with early millet as the cereal.

*Sub-activity 5.7: Time of sowing groundnut living mulch on maize grain yield and soil properties:* The treatments and procedures are the same as those described for sub-activity 5.3, with groundnut as the legume.

*Sub-activity 5.8: Planting density of groundnut living mulch on maize grain yield and soil properties:* The treatments and procedures are the same as those described for sub-activity 5.4, with groundnut as the legume.

<b>Activity 6</b>	Raising and sustaining productivity of integrated crop-livestock systems: Corraling	
Lead Scientist(s)	Asamoah Larbi, Saaka Buah, Bekele Kotu	Institution: IITA, SARI
Other Scientist(s)	Daniel Akakpo, Dominc Sobreh, Shaibu Mellon	
Student(s)	Abdul Rhaman Nurudeen	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

*Sub-activity 6.1: Corraling of livestock for manure effects on productivity of maize-based cropping system:* A split-split-plot design replicated in 3-4 communities per region will be used. Main-plots are no-corraling and corraling with cattle, sheep and goats. Sub-plots are no-tillage, hand hoeing and ploughing; sub-sub plots are recommended (60kg/ha N-40kg/ha P<sub>2</sub>O<sub>5</sub>-40kg/ha K<sub>2</sub>O), medium (90kg/ha N-40kg/ha P<sub>2</sub>O<sub>5</sub>-40kg/ha K<sub>2</sub>O), and higher (120kg/ha N-40kg/ha P<sub>2</sub>O<sub>5</sub>-40kg/ha K<sub>2</sub>O) fertilizer rates for maize. Sub-sub plot size will be 4.5m x 5m (6-row plots). Maize will be spaced at 75cm between rows and 40cm within rows. Weed communities will be evaluated between 2-4 weeks after planting of cereal to determine number of weeds (density) and biomass, to characterize species diversity, and detect introduced species. Grain and fodder yields and soil physical and chemical characteristics will be monitored.

*Sub-activity 6.2: Corraling of livestock for manure effects on productivity of sorghum/millet-based cropping system:* The design, treatments and data to be collected will be similar to sub-activity 3.1, using sorghum as the test crop.

<b>Activity 7</b>	Identification of food/feed crops	
Lead Scientist(s)	Asamoah Larbi	Institution: IITA
Other Scientist(s)	Daniel Akakpo, Dominc Sobreh, Shaibu Mellon	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

On-farm trials initiated in 2013 to identify high-yielding and better quality varieties/genotypes of cereals (maize, sorghum), and legumes (groundnut, cowpea, and soybean) for grain and fodder production will be continued. A new trial will be initiated in 2014 on pigeon pea in collaboration with ICRISAT and Michigan State University. A randomized complete block design replicated in 4-6 communities will be used in all trials. About 10-15 elite varieties/lines of each species will be compared in each trial. Fodder samples will be analyzed for quality. Farmers' field days will be organized to document farmers' preferences. Multi-variate analysis using the yield and quality data will be used to identify clusters of varieties with potential for food (grain), feed

(grain and stover), and feed (stover or crop residues) production. Seeds of promising species will be multiplied for dissemination. Grain and fodder yields, farmer preferences, fodder quality [(crude protein, CP; in vitro organic matter digestibility, IVOMD; neutral detergent fibre, NDF; acid detergent fibre, ADF)] will be documented.

<b>Activity 8</b>	Strengthening institutional capacity for integrated crop-livestock research	
Lead Scientist(s)	Asamoah Larbi	Institution: IITA
Other Scientist(s)	Joel Sam	
Partner(s)	IITA Biometric Unit, INSTI	
Location(s)	Tamale/Bolga/Accra	

### Procedures

Weak statistical and computing knowledge is one of the major constraints to effective dissemination of agricultural research results by most research scientists in sub-Saharan Africa. A recent survey showed that over 90% of agricultural research scientists in the region had difficulties with data analysis and writing up their research for publication. Nearly 40 percent of papers submitted for publication in international journals by research scientists in the region are rejected due to improper analysis and interpretation of research data and bad presentation of research results. Integrated crop-livestock systems predominate in the cereal-legume based farming systems in West Africa. Yet most young researchers, especially women have limited skills in the design and implementation of integrated crop-livestock experiments. The overall objective of this activity is to address these deficiencies and build individual and institutional capacities for data management and analysis by organizing short-courses: 1) Experimental design and analysis using the Statistical Analysis Software (SAS) and 2) Integrated crop-livestock research design and analysis. These courses are follow-ups to those organized in 2012 for male and 2013 for female scientists.

*Sub-activity 8.1: Organize a short-course on experimental design and data analysis:* A 10-day course will be organized in collaboration with the IITA Biometrics Unit. There will be 15-20 participants, 30% of whom will be women. The SAS software will be used for data analysis. There will be three components. Topics to be discussed under Component 1 (data collection) include: variables and measurements, types of scientific data and scientific data collection techniques. Component 2 (Data Management) will concentrate on: software and techniques for data entry and effective retrieval, detection of outliers or influential observations, exploratory/graphical data analysis. The third component (Data Analysis) will be on: categorical modeling of non-quantitative (continuous) response variables, and trend analysis, regression, time series, and prediction.

*Sub-activity 8.2: Organize a short-course on integrated crop-livestock production:* A 5-day course will be organized for 10-15 participants. Topics to be covered include integrated crop-livestock systems, design of integrated crop-livestock experiments, and analysis and presentation of data from integrated crop-livestock experiments.

### 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Improving fallow lands		x	x	x								
2. Integration of livestock under mango	x	x	x	x	x	x	x	x	x	x	x	x
3. Scaling sorghum-cowpea strip	x	x	x	x	x	x	x	x	x	x	x	x
4. Leaf stripping to fill feed gap	x	x	x	x	x	x	x	x	x	x	x	x
5. Living mulch for crop-livestock	x	x	x	x	x	x	x	x	x	x	x	x
6. Corraling effects on soil and crops	x	x	x	x	x	x	x	x	x	x	x	x
7. Identifying food/feed crops	x	x	x	x	x	x	x	x	x	x	x	x
8. Capacity building – crop-livestock	x	x	x	x								

### 8. Capacity building

	Male			Female		
	2014	2015	2016	2014	2015	2016
Farmers	400	600	800	200	200	400
Farmers' associations	7	9	12	4	6	9
Extension officers	10	10	15	6	8	8
Researchers	10	12	17	5	10	12

Input dealers	3	5	6	2	3	5
Policy makers	7	10	12	2	3	6
Development partners	2	3	4	1	2	2

## 9. Student training

	<i>Male</i>			<i>Female</i>		
	<i>2014</i>	<i>2015</i>	<i>2016</i>	<i>2014</i>	<i>2015</i>	<i>2016</i>
BSc	3	5	6	2	3	4
MSc students	1	2	0	1	1	0
PhD students	2	2	4	0	0	0
Interns/non-degree	3	4	4	2	3	3

## 10. Communication and dissemination

	<i>2014</i>	<i>2015</i>	<i>2016</i>
Workshops/meetings	Mar-Jun	Mar-Jun	Mar-Jun
Field days	Sep-Oct	Sep-Oct	Sep-Oct
Conference papers	May-Jul	May-Jul	May-Jul
Journal article	Mar-May	Sep-Nov	Sep-Nov
Others (Exchange visits)	Sep-Nov	Sep-Nov	Sep-Nov

## 11. How are gender issues addressed?

Gender issues are addressed through creation of gender awareness and gender equity in all the project communities. Gender equity issues are mainstreamed in all project meetings. Barriers-to-participation are reduced by offering gender sensitive interventions and the use of appropriate styles and language in all capacity building activities. Women interest groups (WIGs) are promoted and linked to credit.

## 12. Deliverables

- 1 Fallow land management constraints and opportunities identified – August 2014
- 2 Fallow land biodiversity characterized – March 2016
- 3 Options to improve fallow lands – March 2016
- 4 Forage resources under mango plantations identified – December 2014
- 5 A report on integration of sheep into mango plantation – December 2015
- 6 A report on potential of sorghum-cowpea strip cropping for crop-livestock production – end 2015
- 7 Agronomic options to reduce feed gap during the cropping season – December 2015
- 8 A report on potential of living mulch for crop-livestock production – December 2015
- 9 High-yielding and better quality cereal and legume genotypes for food and feed – March 2015
- 10 10 male and 5 female scientists trained in data analysis and crop-livestock production – end 2014

## 13. Expected outputs

- Fallow land management options – March 2016
- Strategies for integrating livestock into mango plantation – December 2015
- A report on integration of sheep into mango plantation – December 2015
- Integrated cereal-legume-livestock options – December 2015
- Strategies to reduce cropping season feed gaps – June 2015
- High-yielding and better quality cereal and legume genotypes for food and feed – March 2015
- At least 15 scientists trained in data analysis and crop-livestock production – December 2014

## 14. Expected outcomes

- Committees are managing the fallow lands
- Farmers are following using improved cropping practices to optimize food and feed production
- Tree crop farmers integrate livestock into their plantations to diversify income
- Students are applying their increased skills in data analysis and integrated crop-livestock research

## 15. Potential impact of outcome

<i>Item</i>	<i>Impact</i>
Household crop production	Reduction in food insecurity
Household livestock production	Meat, milk and egg outputs increase by 10%

Environment (on-farm soil properties)  
Household income

On-farm soil infiltration rate increase by 10%  
Household income increases by 15% through increased sale of products

#### 16. 2014 Budget (US\$)

	Budget Line	IITA
Activity 1	Personnel	15000
	Services	3000
	Supplies	10000
	Travel	2000
	<b>Total</b>	<b>30000</b>
Activity 2	Personnel	15000
	Services	3000
	Supplies	6000
	Travel	2000
	<b>Total</b>	<b>26000</b>
Activity 3	Personnel	16000
	Services	6000
	Supplies	8000
	Travel	4000
	<b>Total</b>	<b>34000</b>
Activity 4	Personnel	14000
	Services	2000
	Supplies	5000
	Travel	2000
	<b>Total</b>	<b>23000</b>
Activity 5	Personnel	15000
	Services	2000
	Supplies	6000
	Travel	1000
	<b>Total</b>	<b>24000</b>
Activity 6	Personnel	15000
	Services	2000
	Supplies	10000
	Travel	3000
	<b>Total</b>	<b>30000</b>
Activity 7	Personnel	14000
	Services	2000
	Supplies	5000
	Travel	1000
	<b>Total</b>	<b>22000</b>
Activity 8	Personnel	19000
	Services	6000
	Supplies	5000
	Travel	5000
	<b>Total</b>	<b>35000</b>
<b>Grand total</b>		<b>224000</b>

## Work-package WP-8

### 1. Title: Land, soil, and water management strategies to intensify cereal-legume farming systems in northern Ghana

#### 2. Research team

<i>Name</i>	<i>Institution</i>	<i>Degree</i>	<i>Research interest</i>	<i>Role</i>
Tim Ellis	IWMI	PhD	Water management	Principal Investigator (Water)
Fred Kizito	CIAT	PhD	Soils, water and landscapes	Deputy PI (Land and Soils)
Wyndham-Wright T	IWMI	MSC	Extension	Communication
Pamela Katic	IWMI	PhD	Economics	Market links
Issahaku Jesiwuni	FONG	-	Farm business	Farming organization
Emmanuel Oubuobie	CSIR (WRI)	PhD	Hydrology	Water balance
Wilson Agyare	KNUST	PhD	Soil, crops, agronomy	Trials on activities 1-4
Francis Tetteh	SRI	PhD	Soil, crops, agronomy	Soil science
Emmanuel Panyan	ARI	PhD	Soil, crops, agronomy	Animal/Agronomic expertise
Asamoah Larbi	IITA	PhD	Agronomy, ruminant nutrition	Lead activity 8
Bekele Kuto	IITA	PhD	Agricultural economics	Economic analysis
Dominic Sobreh	IITA	MSc	Agronomy	Vegetable production
Shaibu Mellon	IITA	BSc	Agricultural economics	Data collection, surveys
Saaka Buah	SARI	PhD	Agronomy, plant nutrition	Monitoring trials – activity 8
Birhanu Zemadim	ICRISAT	PhD	Watershed management	Natural resources, modeling

#### 3. Summary

The work-package aims to develop, test and disseminate water, soil and land management strategies that intensify cereal-legume and livestock farming systems in northern Ghana. There are eight activities, namely: 1) develop soil and land health indicators; 2) characterize land use changes in smallholder systems and identify drivers of land use changes; 3) trade-off analysis and scenario generation for restoration strategies; and 4) on-farm agronomic trials; 5) training of farmers and support to their network of associations; 6) demonstration and implementation of best water and soil management interventions for improved water productivity; 7) monitoring the performance of tested water and soil management options on farm level productivity; 8) watershed management and water harvesting to intensify and diversify crop and livestock production. Activities 1-4 are led by CIAT, 5-7 by IWMI and 8 by IITA.

#### 4. Research problem and justification

Water availability, soil quality and land suitability are basic to agricultural production and all these resources are under increasing pressure in Northern Ghana as food and living standard demands increase. Four key and interlinked constraints to managing these pressures while increasing production and buffering against shocks are:

- Water availability (rainfall, runoff capture to small dams/dugouts)
- Water management (surface management, crop types/combinations amounts and timing of irrigation)
- Soil and land suitability (soil type and local terrain)
- Soil and land management (avoiding soil erosion, soil acidity and salinization)

The principle source of water for farming in northern Ghana is rainfall, which occurs during a relatively short wet season. Rainfall occurs in amounts that cannot always be effectively captured (infiltrated into the soil), stored within the soil and subsequently used by plants. Poor water management when there is “too much” during the growing season, leads to soil degradation via erosion and nutrient loss. Improved water and soil management therefore requires:

- Reducing water, soil and nutrient losses from the farm systems
- Turning these “losses” into “gains” by capturing and storing excess water and using it when it is required during dry periods
- Reducing risk to allow increased production (increased buffer capacity)

Some of the management actions required to manage water and soil better involve moving significant amounts of soil (e.g. dug outs and contour bunds) which is difficult for resource-poor farmers. There is a need for more appropriate tools and implements that can be built and/or maintained by farmers. Equally important, the farmers need methods to identify the most appropriate action for their site conditions, for their enterprise goals (e.g. reduce water logging; undertake some dry season irrigation) and to estimate costs and benefits.

Finally, measurement and monitoring will be required to evaluate the performance of the implemented actions and the capacity of farmers to make decisions with the consideration of the value of water and soil management actions.

## 5. Objectives

Our overall objective in this work-package is to overcome the farmer knowledge constraints to adoption of tried and proven methods for water, land and soil management.

### CIAT:

- 1 Develop soil and landscape health indicators
- 2 Draft one journal paper for sharing with Project team – December 2014
- 3 Characterize land use changes and determine erosion prevalence and degradation hotspots in order to assess landscape ecosystem services – September 2014
- 4 Submit one journal paper – December 2014
- 5 Conduct tradeoff analysis and scenario generation for optimal system productivity and restoration measures decisions
- 6 Determine returns on investment of scenarios generated
- 7 Publish 1 Journal article – June 2015
- 8 Initiate land and conservation measures on-farm and on-station
- 9 Characterize labor demands associated with conservation measures in (1) above
- 10 Closely liaise with other work packages and co-organize intra-regional and inter-regional exchange visits for farmers and extension agents
- 11 Training manuals released on soil and land management strategies for potential scaling out
- 12 Draft one journal paper – December 2015

### IWMI:

- 1 Build farmer capacity in basic water balance and soil-water dynamics for choosing best practice options for their sites
- 2 Provide methods to farmers for estimating the costs and likely benefits of water management interventions
- 3 Linking soil protection to runoff collection and supplementary irrigation practices
- 4 Prevention of water logging through improved seedbed preparation.
- 5 Small dams/dugouts construction to collect excess runoff, using draft animal power
- 6 Develop simple methods for farmers to evaluate the performance of the water management interventions on the basis of water retained, risk reduced and production yield improved
- 6 Measure the effect on interventions on water management (more collected or water logging reduced), production and risk reduction
- 8 Documentation in a report and a as conference paper
- 9 Assist communities make more effective use of rainfall and other water resources in improving their crop and livestock production
- 10 Increase intensification and diversification through sustainable use of water resources and mitigation of drought

## 6. Work-plans and procedures

<b>Activity 1</b>	Determine soil and land health indicators
Lead Scientist(s)	Fred Kizito
Other Scientist(s)	Asamoah Larbi, Tim Ellis, Wilson Agyare, Pamela Katic, Emmanuel Panyan
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri

### Procedures

Most farmers are constrained by a lack of knowledge on appropriate and optimal water and land use options that minimize soil erosion and water resources decline that diminishes system productivity. The activity will rely on extensive field data sets collected during the land degradation surveillance framework (LDSF) excursions conducted in 2013 which will be complemented by new data.

Most farmers are constrained by serious land degradation issues such as inappropriate land use and poor agronomic management which result in soil erosion and water resources decline creating a

downward spiral in system productivity. This work-package will liaise with closely with the “Water Resources” work package led by IWMI as well as the IITA led WP on “Intensification of cereal-legume cropping and crop-livestock systems” to co-develop soil and landscape health indicators.

Field data that will be collected in 2014 will be analyzed but will be complemented with the LDSF field data collected in 2013 in order to develop soil landscape health indicators. The soils will be analyzed for soil fertility and soil physical properties such as texture and saturated conductivity. Local hydrology will be observed, measured, characterized and up-scaled using spatial datasets.

Management actions specific to the other work packages will be determined and implemented once field sites are selected. Collaboration with IITA agronomists and IWMI colleagues will ensure a holistic and inclusive analysis of pertinent attributes. These will serve as a stepping stone for restoration recommendations. A peer reviewed journal paper will be drafted and submitted based on the results.

<b>Activity 2</b>	Characterize land use changes in smallholder systems and identify drivers of land use changes	
Scientists(s)	Fred Kizito	Institution: CIAT
Partner(s)	Tim Ellis, Asamoah Larbi, Wilson Agyare, Francis Tetteh and Emmanuel Panyan	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

Evaluation of the farming landscapes through project work conducted in 2013 revealed that there has been substantial transition of the farming systems and land use patterns. This has taken place alongside other drivers such as low and erratic rainfall and poor land management practices. In order to provide viable interventions and recommendations, the current system needs detailed land use characterization at finer resolution in order to see which land uses are changing the most, the drivers behind these changes and how system productivity is compromised.

Stepwise sequencing of land use change detection methods will be used. This involves data archiving from periodic downloads; data pre-processing; Image training; Classification; Post-processing; Validation; and Change detection. The above procedures will permit us to characterize land use changes in smallholder systems and identify drivers of land use changes. This data will also be correlated to erosion prevalence and degradation hotspots in order to assess landscape ecosystem services and how they can be restored to optimal levels.

<b>Activity 3</b>	Tradeoff analysis and scenario generation for restoration strategies	
Lead Scientist(s)	Fred Kizito	Institution: CIAT
Other Partner (s)	Tim Ellis, Wilson Agyare and Asamoah Larbi	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

### Procedures

There are numerous inputs and decisions that land users, farmers and pastoralists make within farming systems for crop production, manure, food/feed yields, soil, and land and water resources. These are in-turn impacted by both endogenous and exogenous drivers to the system. Conducting a tradeoff analysis coupled with scenario generation will help reveal optimal combinations of technologies for household food production, income generation and landscape integrity.

This activity will build on results derived from activity 1 and 2 to provide optimal tradeoffs assessments. This will be linked to land use change detection, erosion prevalence and land degradation. Management actions specific to the other work packages will be determined and implemented once field sites are selected. The outputs will be translated to a web-based interface for the research community, policy makers and implementing NGOs.

<b>Activity 4</b>	On-station and on-farm trials initiated: Co-designing, co-testing and co-developing improved combinations of soil and land management strategies; Scale-up and out proven small-scale conservation technologies	
Lead Scientists(s)	Fred Kizito	Institution: CIAT



Other Partner(s)	Tim Ellis, Asamoah Larbi, Wilson Agyare, Francis Tetteh and Emmanuel Panyan
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri

#### Procedures

Evaluation of the farming landscapes in 2013 revealed that there has been substantial transition of the farming systems and land use patterns. This has taken place alongside other drivers such as low and erratic rainfall and poor land management practices. In order to provide viable interventions and recommendations, the current system needs detailed characterization in order to see which land uses are changing the most, the drivers behind these changes and how system productivity is compromised. These data will be correlated with erosion prevalence and degradation hotspots in order to assess landscape ecosystem services and how these can be restored to optimal levels.

Prior work in similar sites within the USAID “Quick Wins” framework found that labor was a major limitation in this region. The associated labor input will be determined in order to fully characterize the return of investing in soil and water conservation measures. Use the maps and participatory videos as information sharing and training materials will be used to promote the scaling-up and out of small-scale interventions that increase on-farm land productivity.

<b>Activity 5</b>	Training of farmers and support to their network of associations
Lead scientist(s)	Tim Ellis Institution: IWMI
Other scientist(s)	Fred Kizito
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri

#### Procedures

We will address this major constraint to adoption via a series of staged workshops to introduce and develop concepts and relate them to the farmers’ experiences. The value of water will be placed in a business framework and simple methods will be provided for farmers to rank the value of the various uses of water (e.g. run-on harvesting directly on to crop versus collecting it for irrigation at a later date).

This activity will consist mainly of capacity development of local stakeholders including farmers, extension workers etc. through training workshops in each community. It will involve the following actions: development of appropriate training manuals with input from farmers, NGOs and business development consultants – by September 2014; training of trainers workshop focusing on: water budgets and effects on crop growth and soil health and cost and benefits of water / soil management options. The workshops will be on-going – approximately 4 per year, with the next scheduled for July 2014.

<b>Activity 6</b>	Demonstration and implementation of best water and soil management interventions for improved farm productivity
Lead Scientist(s)	Tim Ellis Institution: IWMI
Other Scientist(s)	Pamela Katic, Emmanuel Panyan, Emmanuel Obuobie
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri

#### Procedures

Adoption of the various options for water management has been low due to poor alignment of interventions with regional issues and site conditions. Here we have selected one prominent water management issue from each region and best-bet management interventions. These will be demonstrated and implemented on farms and via existing farmer networks.

*Sub-activity 6.1: Linking soil protection and supplementary irrigation measures in Upper West Region:* This will involve integrated water and soil management practices to slow degradation of existing cropping land. In this case, contour bunds will be linked with small dams via a “keyline” system to reduce erosion and collect runoff for supplementary irrigation. This will be surveyed and partly installed by September 2015 and fully installed by February 2015

*Sub-activity 6.2: Prevention of water logging through improved seedbed preparation in the Northern Region:* In Northern Region, managing runoff and root zone aeration is widely reported to be a significant impediment to farming. Therefore, we would construct improved tractor-mounted ridging implements from materials such as vehicle parts that are widely available. This would be used for seedbed preparation. The prototype implement will be constructed by July 2014 and tested and evaluated by August 2014. Improved seedbeds will be prepared during this period and will approximate 10 hectares.

*Sub-activity 6.3: Small dams/dugouts construction using draft animal power in Upper East Region:* This is a proven technology that can be easily promulgated and will make better use of draft animal resources during the growing and dry seasons and will help retain youth during slack times. Simple implements will be built from locally available materials and animals and handlers will be trained in their use. During the growing season, there will be community consultation and training of animals and handlers and surveying of sites will be complete by September 2014. We expect the structure to be commenced before harvest (October-November) and completed over the dry season in preparation for the first rains in April 2015.

<b>Activity 7</b>	Monitoring the performance of the interventions on improved water management and potential improved productivity	
Lead Scientist(s)	Tim Ellis	Institution: IWMI
Other Scientist (s)		
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

This participatory research will also be adapted as new understanding of the performance of interventions and implementation methods become available. To quantify these and to inform improvements in techniques and dissemination, water budgets and changes in production must be measured and monitored.

Simple methods for measuring rainfall and runoff will be developed and farmers will be trained in their application and data recording. Data will be collated by extension agents and “trained farmers” via existing networks and will give farmers an indication of potential yields for each season. Any measurable changes in (say, runoff or supplementary irrigation available) will be detected and their effect on production and risk reduction will be measured. On the basis of changes in the local water budget (e.g. less runoff wasted and more supplementary irrigation available) any recommended improvements in the interventions will be determined from the data and feedback from farmers.

<b>Activity 8</b>	Watershed management and water harvesting to improve the supply of water for intensive and diversified crop and livestock production	
Lead Scientist(s)	Asamoah Larbi	Institution: IITA
Other Scientist(s)	Birhanu Zemadim, Fred Kizto, William Agyare, Shaibu Mellon,	
Consultant(s)	To be identified	
Location(s)	Samboligo	

#### Procedures

*Sub-activity 8.1: Select representative water shed:* Selection and characterization of representative watersheds and specific sites located within participating communities for demonstrating improved technologies. Sites will be selected based on: (i) being representative of biophysical and socioeconomic variability of the target areas, (ii) rainfed farming/livestock production is practiced at the sites, (iii) easily accessible and central to a large number of farming communities, (iv) farmers are interested in the project and willing to provide their land, and (v) having the major problems within the watershed that need solution. GIS and field visits to the sub-basins will be used to decide on the sites that satisfy the above criteria.

*Sub-activity 8.2: Harvest water for crop and livestock use:* Where appropriate, construct macro-catchment water harvesting structures including check dams and water spreading structures. Macro-water harvesting structures may also provide a source of water for livestock and domestic use, and investigate measures required to ensure that the harvested water is of potable quality.

Based on existing indigenous knowledge of water use, test options for micro-catchment water harvesting, use of contour bunds, etc., that improve on traditional water harvesting methods, and test options for utilizing water more efficiently in irrigated cropping. Possible experiments will include:

- Monitoring nutrient losses with natural runoff under different crop covers
- Minimizing surface run-off and conservation of moisture through strip cropping
- Compare tillage practices with cover crops for conservation of moisture
- Study the efficiency of various vegetative structures to control erosion

Work with communities in establishing rights of access and use to harvested water sources and facilitate the establishment of community water management organizations responsible for maintenance of communal water harvesting structures, watershed management and for maintaining rights of access and use.

*Sub-activity 8.3: Assess environmental and socioeconomic impacts:* A few informative and easily measured indicators will be identified to assess impact of the activity on the following: water availability, soil structure and fertility, agricultural productivity, equity in common-resource use, income and living conditions of the household, vegetative cover and agro biodiversity, and ecosystem balance. A simple monitoring and evaluation mechanism will be established so that the impact can be assessed during and beyond the duration of the project. An *ex ante* assessment of potential impact will be carried out using rapid, participatory rural appraisals, case studies, farm survey, field measurements, etc. These studies will also provide information on potential problems requiring further research.

*Sub-activity 8.4: Assess institutional and policy options to improve water management and use:* (i) review and analyzing policies in the areas targeted. Review policy documents and its application rules and procedures, as related to the legislature governing the status and use of common property resources, (ii) interview policy makers and end-users for assessment of the policy and its application, and (iii) prepare policy briefs and hold workshops with policy makers, NARS, end-users and other stakeholders on policy issues.

## 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
<b>7.1 Land and Soil Management</b>												
1. Soil/land health metrics developed	x	x	x	x	x	x	x	x	x	x		
2. Land use change detection	x	x	x	x	x	x	x	x	x	x	x	
3. Tradeoff analysis and scenario generation for improved crop-livestock systems	x	x	x	x	x	x	x	x	x	x		
4. Strategies to integrate soil-water conservation in crop-livestock systems	x	x	x	x	x	x	x	x	x	x		
<b>7.2 Water Management</b>												
1. Improved understanding of water cycles to guide choice of water management options		x	x			x		x	x			
2. Water management interventions demonstrated and applied			x		x	x		x	x			
3. Monitoring performance of appropriate and tested water and soil management options on farm level productivity					x	x	x	x	x	x	x	
4. Watershed management		x	x	x	x	x	x	x	x	x	x	x

## 8. Capacity building

	Male			Female		
	2014	2015	2016	2014	2015	2016
<b>8.1 Land and Soil Management</b>						
Farmers	1000	1300	2000	600	1000	1500
Extension officers	10	10	10	5	5	5
Researchers	8	10	12	6	6	12

Policy makers	8	14	20	7	10	12
Development partners	8	7	6	5	8	10
<b>8.2 Water Management</b>						
Farmers	200	500	500	500	500	500
Extension officers	10	10	10	10	10	10
Researchers	5	5	5	5	5	5
Policy makers	5	5	5	5	5	5
Development partners	2	2	2	2	2	2

## 9. Student training

	<i>Male</i>			<i>Female</i>		
	2014	2015	2016	2014	2015	2016
<b>9.1 Land and Soil Management</b>						
PhD students		1	1		1	1
MSc students	1	1	1	1	1	1
Interns/non-degree	3	4	3	3	2	2
<b>9.2 Water Management</b>						
PhD students			1			1
MSc students		1	1		1	1
Interns/non-degree	2	2			1	1

## 10. Communication and dissemination

	2014	2015	2016
<b>10.1 Land and Soil Management</b>			
Workshops/meetings	Mar-Jun	Mar-Jun	Mar-Jun
Field days	Sep-Oct	Sep-Oct	Sep-Oct
Conference papers	May-Jul	May-Jul	May-Jul
Journal article	Mar-May	Sep-Nov	Sep-Nov
Others (Exchange visits)	Sep-Nov	Sep-Nov	Sep-Nov
<b>10.2 Water Management</b>			
Workshops/meetings	Mar-June	Mar-June	Mar-June
Field days	Aug-Sep	Aug-Sep	Aug-Sep
Conference papers	Nov-Dec	Nov-Dec	Nov-Dec
Journal article	-	Jan-Feb	Jan-Feb
Others (Farmer-to-farmer exchange visits)	-	Feb-May	Feb-May

## 11. How are gender issues addressed?

The most powerful tool we have to address gender issues is to promote business thinking and skills amongst women and youth, as well as men. Workshops conducted during the previous project demonstrated that willingness and aptitude of all gender groups for the business-related concepts for water and soil management. The female participants, although less outspoken, showed particular interest and understanding of the material and we will build on this in this work package. Where situations are better-suited to segregation of genders for group work, we will address these as they arise and on local advice and customs.

In collaboration with other work packages, gender issues are addressed through creation of gender awareness and gender equity in all the project communities. Gender equity issues are mainstreamed in all project meetings. Barriers-to-participation are reduced by offering gender sensitive interventions and the use of appropriate styles and language in all capacity building activities. This work package will strive to ensure inclusion of women groups in the project activities in order to impart skills and knowledge to women.

## 12. Deliverables

### CIAT:

- 1 Soil and landscape health indicators developed by June 2014
- 2 One journal/conference paper drafted by December 2014
- 3 Publish 1 peer reviewed research article (submission in December 2014)

- 4 Build partner capacity through knowledge sharing and practical demonstrations - ongoing
- 5 Report on tradeoff analysis and scenario generation for optimal system productivity and restoration measures decisions released in 2015
- 6 Dissemination: Approximately 3,000 people from the general public, farming community reached through the web-based interface – ongoing to 2015
- 7 1 Journal paper submitted by June 2015
- 8 Training materials released for small-scale farmers on soil and land management strategies – December 2014
- 9 Change detection maps within crop-livestock target zones produced – by December 2014
- 10 Degraded hotspots identified and mapped – by March 2015
- 11 Ecosystem services within crop-livestock target zones assessed, quantified and mapped – by June 2015
- 12 1 Peer-reviewed journal article submitted in 2016

**IWMI:**

- 1 Demonstration manuals – August 2014
- 2 Training of trainers workshop report – September 2014
- 3 Training workshop report – October 2014
- 4 After workshop evaluation report – December 2014
- 5 Keyline systems surveyed and marked out in cleared and uncleared land – September 2014
- 6 Keyline system implemented – March 2015
- 7 Collected runoff available for supplementary irrigation – April 2015 (rains permitting)
- 8 Method developed for leveling the surface rough cultivation using existing tillage implement – July 2014
- 9 Prototype tractor-mounted ridger constructed and tested to reduce water logging of fields cultivated by machinery – July 2014
- 10 At least 3 fields prepared with ridges to reduce the water logging effects frequently experienced with existing mechanized methods – August 2014
- 11 At least 10 items simple earthmoving equipment suitable for draft animals constructed – October 2014
- 12 At least 10 pairs of animals and associated animal handlers trained in earthmoving via draft animal methods – October 2014
- 13 At least one dugout constructed to allow supplementary irrigation – April 2014
- 14 Rain gauges constructed and deployed – July 2014
- 15 Three agents trained to collect and clean data – August 2014
- 16 Runoff installations deployed – July 2014

**13. Expected outputs**

- Report on soil and land health indicators
- A publication on land use change dynamics in the target sites shared with project partners for further insights and input
- Tradeoff analysis and scenario assessments that help guide investments in target areas for sustainable intensification generated; including land and crop suitability classification for increasing productivity in smallholder systems
- Implementation manuals on soil and land management strategies for scaling out of proven small-scale soil and water conservation technologies disseminated
- Improved understanding of water cycles that guides the choice of appropriate water management options
- A range of water and soil management interventions evaluated and disseminated among network of farmers
- Recommendations based on performance of appropriate and tested water and soil management options on farm level productivity documented in diverse outlets

**14. Expected outcomes**

- Households adopt technologies to improve soil, water and land management
- -More households are harvesting water for off-season vegetable production

## **15. Potential impact of outcome**

<i>Item</i>	<i>Impact</i>
Increased system productivity	Landscape indicators and scenarios will allow for targeted interventions that result in increased crop yields through wise combinations of technologies thus intensifying crop-livestock systems
Improved natural resource base	Soil and water conservation measures will impart greater resilience in landscapes thus help with restoring ecosystem services and biodiversity
Climate change adaptation	Land use change studies provide mitigation strategies that impart climate change adaptation mechanisms to households

**16. 2014 Budget (US\$)**

	Budget Line	CIAT	IWMI	IITA
Activity 1	Personnel	3000		
	Services	2500		
	Supplies	2000		
	Travel	1500		
	<b>Total</b>	<b>9000</b>		
Activity 2	Personnel	15000		
	Services	2000		
	Supplies	2000		
	Travel	2000		
	<b>Total</b>	<b>21000</b>		
Activity 3	Personnel	10000		
	Services	5000		
	Supplies	23000		
	Travel	2000		
	<b>Total</b>	<b>40000</b>		
Activity 4	Personnel	10000		
	Services	8000		
	Supplies	8000		
	Travel	4000		
	<b>Total</b>	<b>30000</b>		
Activity 5	Personnel		10000	
	Services		1000	
	Supplies		2000	
	Travel		2000	
	<b>Total</b>		<b>15000</b>	
Activity 6	Personnel		25000	
	Services		10000	
	Supplies		25000	
	Travel		5000	
	<b>Total</b>		<b>65000</b>	
Activity 7	Personnel		14000	
	Services		2000	
	Supplies		2000	
	Travel		2000	
	<b>Total</b>		<b>20000</b>	
Activity 8	Personnel			10000
	Services			12000
	Supplies			8000
	Travel			4000
	<b>Total</b>	<b>100000</b>	<b>100000</b>	<b>34000</b>

## Work-package WP-9

### 1. Title: Managing natural resources to increase watershed productivity in southern Mali

#### 2. Research Team

<i>Name</i>	<i>Institution</i>	<i>Degree</i>	<i>Research interest</i>	<i>Role</i>
Birhanu Zemadim	ICRISAT	PhD	Watershed Management,	Principal Investigator (PI)
Augustine Ayantunde	ILRI	PhD	Livestock management	Deputy PI
Mary Ollenburger	WUR	MSc	Farm systems research	Graduate student
Clarisse Umutohi	ILRI	MSc	Conflict management	Graduate student
Bougouna Sogoba,	AMEDD	MSc	Biomass assessments	Contact local partner
Gilbert Dembélé	AMEDD	MSc	Biomass assessments	Technician

#### 3. Summary

This work-package targets capacity building, existing natural resources (NRM) options, conventions on NRM, and promotion of appropriate technologies of NRM to enable systems productivity while reducing pressure on the ecosystem and conflicts over the use of NRM. The activities include training, biomass assessment in cropped and non-cropped areas; mapping of grazing itineraries; development of community natural resource maps and trajectories; characterization of land, water, and ecosystem conditions and management; documentation of transhumance practices; establishing a watershed area to characterize the biophysical and social characteristics of NRM and to integrate various research components; farm to watershed level monitoring and modeling; documentation of existing local conventions; development of a plan for strengthening implementation of existing local conventions in the project community; conflict analysis and management; and experimentation on appropriate land and water management technologies.

#### 4. Research problem and justification

The existing farming systems in the project sites entail use of both individual land holdings for crop farming and communal natural resources such as grazing areas for livestock. The use of common properties directly impact on the household farm level productivity through nutrient flows between individual and communal lands. Hence, there is need for sustainable and productive management of the common properties for the benefit of all rural households. Considering the challenges of rainfed farming and changes in climatic patterns in the region one of the many solutions to achieve the main goal of the project is through sustainable management of natural resources. Sustainable management of natural resources (soil, fodder, water, grazing areas, trees, livestock and community) ensures improved livelihoods of the rural communities. Well managed resources will ease tensions among communities and pressures on the natural eco-systems. Sustainable management of natural resources ensures systems productivity and hence leads to improved crop-livestock productivity while ensuring the safety and sustainability of the natural ecosystem. The work-package contributes to research output RO2, Integrated Systems Improvement, and RO3, Scaling and Delivery of Integrated Innovations.

#### 5. Objectives

- 1 Quantify peak and seasonal biomass and feed availability at village scale
- 2 Characterize grazing itineraries and pasture utilization by village herds
- 3 Share information about current pasture availability and management with local stakeholders
- 4 Document the existing local conventions in the study sites particularly their strengths and weaknesses, and processes of elaboration
- 5 Identify strategies to strengthen the implementation of existing local conventions
- 6 Analyze the proximate and distant causes of conflict over natural resource use in the study sites
- 7 Identify technical, social and institutional innovations for participatory management of conflict
- 8 Assess the effects on transhumant practices on natural resource management in the study sites
- 9 Characterization of watersheds and their communities for sustainable agricultural intensification
- 10 Identification of appropriate natural resources management (NRM) options to improve sustainable development
- 11 Determination of impacts of various NRM intervention options from farm to small watershed scale using biophysical modeling tools
- 12 Develop scenarios for framing model explorations, model structure and rules in workshops with farmers and stakeholders
- 13 Develop agent-based model to explore impacts of sustainable intensification options at farm to village scale



- 14 Use models in participatory workshops to explore opportunities and trade-offs for different sustainable intensification practices at farm and village scale

## 6. Work-plans and procedures

<b>Activity 1</b>	Village-level biomass and pasture assessment and mapping of grazing itineraries	
Lead Scientists(s)	Birhanu Zemadim	Institution: ICRISAT
Other Scientist(s)	Gilbert Dembélé, Bougouna Sogoba	
Student(s)	Mary Ollenburger	
Location(s)	Koutiala, Bougouni and Yanfolila districts	

### Procedures

*Sub-activity 1.1: Village-level biomass and pasture assessment and mapping of grazing itineraries:* Biomass assessments have been begun in Sibirila and Dieba villages in Bougouni (and will be conducted by other projects in Koutiala). This activity will continue until September 2015 and will be complemented with animal census information and grazing itineraries. Annual peak biomass assessment in pasture was complemented by crop and weed information from the detailed farm characterization survey and sampling conducted by Wageningen UR in 2013; crop field sampling will be repeated in 2014 on the same 19 farms in two villages to characterize feed resources available throughout the year.

Pasture sampling follows a hierarchical sampling strategy: non-cropped areas have been stratified by land use types. A total of 12 sampling boxes per village were identified by selecting points at random from within each land use type. Within each box, a systematic sample of five 1m x 1m quadrats is sampled for total biomass, species composition, and subsamples are taken for dry matter determination and quality analysis. Sampling is repeated every two months in adjacent quadrats to estimate seasonal biomass and forage availability.

*Sub-activity 1.2: Mapping of grazing itineraries:* In order to complement the assessment of available feed resources at village level, utilization patterns must be established. To this end information on herd composition and grazing itineraries will be collected for 10 village herds in the villages of Sibirila and Dieba. Animal numbers, types, ages, and gestational status will be recorded and movements will be tracked using GPS collars throughout one year to estimate pasture utilization and pressure on grazing resources in different parts of the village territory. This information will help people make informed decisions about use of pasture resources. Thus information from this activity can contribute to reinforcing local conventions.

<b>Activity 2</b>	Documentation and validation of existing local conventions	
Lead scientists(s)	Augustine Ayantunde	Institution: ILRI
Graduate students	Clarisse Umutohi, ILRI	
Location(s)	Koutiala, Bougouni and Yanfolila districts	

### Procedures

*Sub-activity 2.1: Documentation of existing local conventions:* This activity will build on the on-going surveys on the local conventions in the project sites. Group discussions among the local administrative authorities, technical services and customary leaders will be conducted as well as individual interviews to document the processes involved in the elaboration, implementation, monitoring and evaluation of the existing local conventions. Between 25 and 30 individuals in each community will be interviewed to document the perception and knowledge of local populations of local conventions governing natural resource management in the community. In addition, this study will also assess the knowledge, attitude and skill of the community members in relation to natural resource management interventions including local conventions. Results of this activity will provide useful information for activities on conflict management and transhumant practices (in the study sites).

*Sub-activity 2.2: Validation workshops on local conventions:* Building on the ongoing study on the analysis of the strength and weakness of the local conventions started in 2013 in the intervention communities, we are going to organize a validation workshop to share the results of the study in the project sites and develop plan for strengthening the elaboration and implementation processes of the existing local conventions in the project communities. Technical and judicial experts will be brought in to build the capacity of the key stakeholders at local government level as well as traditional leaders regarding the elaboration, implementation, monitoring and evaluation of the local conventions. Ten opinion leaders including two women who are well informed about the existing local conventions will be invited from each intervention community for the workshop which

will take place in Bougouni and Koutiala. In addition, officials from the administrative and technical services will be invited for the workshop. After validation of the results, there will be group discussion per community on plans to strengthen the existing local conventions including the technical, institutional and social interventions including land use plans. Later, another workshop will be organized to assess the implementation of the proposed plans in each community. Each workshop will last for 1 day. Results of these workshops will feed into Activity 3, WP-M1 on multi-stakeholder national workshop for feedback on results from the project activities.

<b>Activity 3</b>	Participatory conflict management	
Lead scientists(s)	Augustine Ayantunde	Institution: ILRI
Graduate students	Clarisse Umutoni, ILRI	
Location(s)	Koutiala, Bougouni and Yanfolila districts	

### Procedures

*Sub-activity 3.1: Workshops on conflict management:* Conflict over natural resource use is common in Sudano-Sahelian zone and could be attributed to many factors. Conflict is best managed at the local level but this depends on the leadership skills and capacity of the local institutions. Where there is strong local institutions, most cases of conflict are normally resolved. Given the importance of local institutions in managing and resolving conflict over natural resource use, it is necessary to build their capacity. To build the capacity of local institutions in conflict management, a training workshop will be organized in Bougouni and Koutiala. Ten participants from the local communities will be invited including the key stakeholders from the local institutions including formal administrative authorities, customary leaders and leaders of key social groups. The training will address methods/tools for participatory conflict analysis, conflict timeline, mapping conflict over natural resource use, social relations and communication, and 4Rs analysis (Right, Responsibility, Response, and Relationship) of conflict management. A consultant from Mali will lead the training which will be conducted in Bougouni and Koutiala. The workshop will last for 2 days. Results of these workshops will feed into multi-stakeholder national workshop for feedback on results from the project activities.

*Sub-activity 3.2: Participatory conflict analysis and management:* Farmer-herder conflicts are enduring features of social life in the Sudano-Sahelian zone. This activity will focus on participatory analysis of conflict management in the intervention communities with the aim of determining the proximate and long-term causes of conflict over natural resource use, evaluating the appropriateness of existing institutional arrangements for managing conflicts and identifying innovative options and incentives to reduce the incidence and severity of conflicts. The research will employ both quantitative and qualitative survey instruments to collect information on historical micro-geographies of cropping and herding in the area encompassing village territory; local day-to-day relationships between transhumance herders, settled herders, and farming households at the study site; nodes of communication under different types of disagreements and negotiate settings; documentation of past conflicts and role of government officials, customary authorities and NGOs in conflict management. The group discussions will involve key stakeholders in conflict management in the communities as well as administrative authorities. In addition, between 25 and 30 individuals will be interviewed. This activity links well with activity on documentation of existing local conventions and will inform identification of strategies to strengthen the local conventions.

*Sub-activity 3.3: Documentation of transhumance practices:* This activity on transhumant practices and the impact on natural resource management will document the current practices, and the local perceptions on benefits and constraints of transhumance. Group discussions as well as individual surveys will be conducted in the intervention communities. Attempt will be made to map the transhumant routes or livestock corridors in the land use maps of the communities. The goal of the mapping is to ensure clear demarcation of the animal corridors to ensure unhindered livestock mobility and encroachment through crop farming. Stakeholders' meeting will be organized on measures to respect the animal corridors. This activity links well with activity on documentation of existing local conventions and will inform identification of strategies to strengthen the local conventions. Also, results from this activity will enhance better understanding of the maps of the grazing itineraries.

<b>Activity 4</b>	Establishing and characterization of watershed area for integration of research activities	
Lead Scientists(s)	Birhanu Zemadim	Institution: ILRI
Student(s)	Mary Ollenburger, Gatien Falconnier, Djelika Toure	
Location(s)	Koutiala	

## Procedures

*Sub-activity 4.1: Establish and characterize a watershed area for integrated research:* A watershed or delineated area will be identified within the Africa RISING action village areas to integrate multiple activities, and to identify major researchable issues that require integration of different research components. It is expected that activities will be worked to produce a common output. In establishing watershed (delineated) area several social and biophysical characteristics will be taken into account. For example the willingness of communities to be part of the watershed research program is a priority concern. Thus approval from the local government authorities and local village elders is important. Physiographic characteristics namely presence of elevation, different agronomic practices (rainfed, small scale irrigation systems, land, labor, market will be considered).

In the identified watershed existing data on local farm practices, water uses, traditional land and water management activities and opportunities for improvement are studied. Similarly physiographic characteristics including drainage density, slopes are evaluated. Agro-hydrological characteristics including climatic conditions, land use and land cover pattern and soil nutrients are evaluated. Existing eco-system functions involving benefits that build up from the use an integrated management of natural resources capital are evaluated in the watershed program. Local land and water management interventions at both farm and community (watershed level) are mapped using GPS to characterize the spatial extent of natural resources management in the watershed. This activity generates evidence on the current NRM to support the information needed in sub-activities 3.3 and 4.2. The traditional practices in NRM will be closely aligned with the identification, validation and strengthening of local conventions.

*Sub-activity 4.2: Farmers training on contour bund technology (CBTs):* At least two CBT trainings will be organized (one in Koutiala and one in Bougouni). Contour Bunding Technology (CBT) has been widely applied in few regions of Mali since 1995 as an effective land and water management intervention. There are existing potentials to further intensify its application which requires training farmers on its use and practices to improve household incomes and conserve the resource capital. At least two CBT trainings will be organized (one in Koutiala and one in Bougouni) in Sikasso region of southern Mali in close collaboration with IER and AMEDD. The current activity will be aligned with the social and biophysical characteristics of the R4D platforms developed in Koutiala and Bougouni.

*Sub-activity 4.3: Experimentation on appropriate land and water management technologies:* Contour Bunding Technology (CBT) has been widely promoted as a sustainable land and water management technology in Mali. Benefits including runoff control and prevention of soil erosion and extension of crops growing period were the main targets of the CBT applications. However since its application there are limited research activities to understand its impact on water runoff, erosion, crop productivity and ecosystem services. Therefore it is planned to experiment the CBT technology in few Africa RISING villages and integrate other programs for example the farm/field level intensification options of the Africa RISING program. The experimentation will be done in the identified watershed where part of the watershed area will be treated for CBT and part of the area is reserved for control. In the treatment and control portions various crop intensification options for example levels of fertilizer/manure applications, crop varieties, treatments and management options will be studied to understand the changes in crop yield, biomass and fodder productivity and the gains in eco-system services. Similarly monitoring stations (runoff, soil moisture, sediment, ground water level) will be established in both control and treatment and the changes in biophysical and eco-system conditions will be monitored in close collaboration with local communities. Here communities will be trained in participatory monitoring skills. Hence output of the CBT practices will be experimented through biophysical monitoring and crop productivity. Monitored data in terms of changes in water level in identified boreholes and streams outlet locations, soil moisture status, erosion and sedimentation rates provide biophysical impacts of CBT interventions in the watershed. Similarly crop yield, biomass, regeneration of vegetation will be monitored both at control and treated watershed to quantify the impact of intervention. Spatial data will be mapped using GIS and data analysis help to characterize the in situ water use efficiencies, land degradations and intensification options for crop productivity status from farm to small watershed scale. Similarly the various crop intensification options under technologies of land and water management will support the development of scenarios for modeling. The activity will look in to efficiency of farm systems under various intensification options.

*Sub-activity 4.4: Modeling from field to watershed level using biophysical model:* Various farm to small scale watershed intervention outputs will be combined to develop appropriate natural resources management practices. Information obtained from the baseline reports, field investigations and experimental analysis will be

modeled using the Soil and Water Assessment Tool (SWAT) model. The model simulates the Blue and Green Water and help to simulate the gains in biophysical settings due to intervention options on land and water management practices. The model also simulates crop productivity under various land and water management options. Monitored data from the watershed will be used to calibrate and validate the model. The validated model will be used to develop various scenarios that help to intensify the farm/watershed scale intervention of land and water management. Hence impacts of land and water management practices will be established at a scale which is appropriate to intensify agricultural productivity in the study region.

<b>Activity 5</b>	Integrated modeling of intensification and land use at village level	
Lead Scientists(s)	Birhanu Zemadim	Institution: ICRISAT
Other Scientist(s)	Katrien Descheemaeker	
Student(s)	Mary Ollenburger	
Location(s)	Bougouni district –Sibirila and Dieba villages	

### Procedures

In Sikasso region there are strong interactions both among farms and between farms and the surrounding non-cropped areas. Therefore it is important to integrate farm-scale intensification and larger-scale land use and natural resource management, to assess potential impacts of technologies and institutions. Agent-based models can integrate biophysical and social system components and serve as tools for informing discussion of scenarios for system change. Summary models of farm system components and processes in non-cropped areas will be based on results from field trials, farm characterization (WUR situation analysis), and biomass assessment grazing itineraries. Decision algorithms will be built in collaboration with farmers through focus group discussions and descriptive games. Scenarios for possible futures will be developed in workshops with key stakeholders and technology options as well as institutional innovations will be explored under these scenarios. This will allow us to explore possible effects of integrating farm-scale technologies with scenarios involving strengthened local conventions and improved management of natural resources at larger scales. Models will be used to explore ways to minimize trade-offs between improving farm production and farmer livelihoods and conserving natural resources, in discussion with farmers and local stakeholders.

### 6. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
Village-level biomass and pasture assessment and mapping of grazing itineraries	X	X	X	X	X	X	X	X	X			
Documentation and validation of existing local conventions	X	X	X	X	X	X	X					
Participatory conflict management		X	X	X	X	X	X	X	X			
Establishing and characterization of watershed area for integration of research activities		X	X	X	X	X	X	X	X	X	X	X
Integrated modeling of intensification and land use at village level					x	x		X	X	X	X	X

### 7. Capacity building

	Male			Female		
	2014	2015	2016	2014	2015	2016
Farmers	150			50		
Researchers	4			2		
Policy makers	18			10		
Development partners	10			6		

## 8. Student training

	<i>Male</i>			<i>Female</i>		
	<i>2014</i>	<i>2015</i>	<i>2016</i>	<i>2014</i>	<i>2015</i>	<i>2016</i>
MSc students	2	2	2	2	2	2
PhD students	1			2		
Interns/non-degree	4	4	4	4		

## 9. Communication and dissemination

	<i>2014</i>	<i>2015</i>	<i>2016</i>
Workshops/meetings	8	8	8
Field days	2	2	2
Conference papers	1	2	
Journal article		2	3
Others (reports, theses)	5	2	2
Database (Social, GIS, ect.)	2	2	2

## 10. How are gender issues addressed?

Women groups are trained on the sustainable management of natural resources. Activities encourage women to earn incomes through household farming practices.

## 11. Deliverables and publications

- 1 Interim report on peak biomass quantity and quality in 2013 – June 2014
- 2 Final report on annual peak and seasonal biomass quantity and fodder quality assessment – March 2015
- 3 Technician recruited and trained in use of GPS – March 2014
- 4 Map of grazing itineraries and pasture use intensity – June 2015
- 5 Report and journal article – March 2016
- 6 Workshop report on conflict management – September 2014
- 7 Journal article on conflict management – Draft manuscript December 2015
- 8 Map of transhumance routes – March 2015
- 9 Report on transhumance practices and their effects on natural resource management – March 2015
- 10 Report on the choice of watershed and biophysical characteristics – December 2014
- 11 Test sites with contour bunds for monitoring biophysical variables and intensification options established
- 12 Reports on two (2) workshops on CBT for 40 farmers in Bougouni and Koutiala – December 2014
- 13 GIS maps of watershed boundary, contour bund sites, biophysical monitoring sites, and database on crop productivity – June 2015
- 14 Reports of model development and exploration workshops – December 2015
- 15 Journal Article. Draft Manuscript on Watershed Characterization – June 2015
- 16 Journal Article. Draft Manuscript on CBT assessment and Model Development – December 2015
- 17 Model development workshops reports – June 2015
- 18 Model exploration workshops reports – March 2016
- 19 Working model code made available – June 2016

## 12. Expected outputs

- Information is available on productivity and management of grazing resources
- Existing local conventions on natural resource management are identified, described and strengthened
- Integrated technologies for natural resources management are identified and tested
- Interactions between farm-scale intensification and village level land use and productivity are modeled

## 13. Expected outcomes

- Farmers are using the technologies developed to improve their traditional farming practices
- Communities manage the natural resources in a way that improves their livelihoods and minimizes conflicts over natural resource

**14. 2014 Budget (US\$)**

		ICRISAT	ILRI	IER	AMEDD
Activity 1	Personnel	9000			2500
	Services	8000			1000
	Supplies	1500			500
	Travel	7500			500
	Total	26000			4500
Activity 2	Personnel		26000		2500
	Services		7400		1000
	Supplies		9400		500
	Travel		3200		500
	Total		46000		4500
Activity 3	Personnel		33000		2500
	Services		13000		1000
	Supplies		12000		500
	Travel		6000		500
	Total		64000		4500
Activity 4	Personnel	20000		10,000	2500
	Services	15000		5000	2000
	Supplies	3500		5000	1000
	Travel	11500		7500	1000
	Total	50000		27500	6500
Activity 5	Personnel	0			
	Services	1000			
	Supplies	500			
	Travel	1000			
	Total	2500			
<b>Grand total</b>		<b>76000</b>	<b>110000</b>	<b>27500</b>	<b>20000</b>

## Work-package WP-10

### 1. Title: Improving household nutrition through agricultural and behavioral change communication and value addition in Ghana and Mali

#### 2. Research Team

Country	Name	Institution	Degree	Research interest	Role
Ghana	Mahama Saaka	UDS	PhD	Public health nutrition	Principal Investigator (PI)
	Asamoah Larbi	IITA	PhD	Crop-livestock, feeds	Deputy PI
	Roland Kanlisi	HI	MSc	Veterinary Epidemiology	Contact, Heifer International
	Sofo Mutaru	GHS	MSc	Community health	Assistant coordinator
	Jacob Mahama	GHS	MPH	Public health	Coordination
	Bridget Parwar	WIAD	MSc	Community health	Technical assistants
	Daniel Akakpo	IITA	MPH	Agronomy	Field layout, data collection
	Marshak Abdulai	SARI	PhD	Breeding	Vegetables seed production
	Anehmbom Mundi	ICRAF	Msc	Post harvest, nutrition	Principal Investigator (PI)
Mali	Eva Weltzien	ICRISAT	PhD	Sorghum breeding	Deputy (PI)
	Honafing Diarra	AVRDC	BSc	Nutrition	Training on nutrition
	Pierre Coulibaly	AMEDD	BSc	Animal Nutrition	Field Extension

#### 3. Summary

This work-package aims at improving nutritional status of farm-families through a community-based 'Behavior Change Communication' training and an 'Agricultural-based Diet Diversity' approach. An expert workshop will be organized to outline nutritional activities, results of household nutritional surveys organized in 2013 will be published into a booklet and peer reviewed journal papers, women and nursing mothers will be empowered through training in best nutritional practices, and studies will be initiated to compare different approaches of improving dietary diversity of farm-families. The work-package is linked to those on crop (legumes, vegetables) and livestock (sheep, goats, poultry and pig) production.

#### 4. Research problem and justification

There is high potential for cultivation of nutritious crops (legumes and vegetables) and rearing of livestock (sheep and goats) and poultry; and processing, storage and use of nutritious foods. Yet, the nutritional status of farm-families, especially pregnant women, breast-feeding mothers and children aged 6-36 months at the Africa RISING intervention communities in northern Ghana and southern Mali is generally low. In Ghana for example, a baseline household nutrition survey in the Africa RISING intervention communities in Ghana showed that most of the infant and young child feeding (IYCF) practices were sub-optimal and need to be improved. Less than 10% of children were fed on vitamin A rich fruits and vegetables. Consumption of animal protein (meat, milk and eggs) was reported in less than 12% of children. Legumes consumption was reported in 45.7% of the households.

We hypothesize that the nutritional status of farm-families in the Africa RISING intervention communities can be improved through a community-based 'Behavior Change Communication (BCC), training and an 'Agricultural-based Diet Diversity (ADD)' approach which encourages the production and consumption of varied sources of micronutrients and essential amino acids, usually through small-scale home production of crops (vegetables and legumes) and livestock that improves access to a diverse, high quality diet using community programming that emphasizes nutrition, health and agricultural education.

Sales of livestock and their products (milk and dairy products, meat, wool) are major sources of income for smallholder livestock producers in the target communities. Adding value to livestock products through processing to capture niche markets and to improve profit margins is limited. When value addition is practiced (e.g., milk-processing), it is mostly done by women using traditional, outmoded, and time consuming methods which increases the work-load of women and results in low-quality products with limited shelf-life. It is hypothesized that helping farmer adds value to their products could improve household income and nutrition.

This activity aims at developing the capacity of household in the Africa RISING target communities improve their nutritional and income status.

#### 5. Specific objectives or research questions

The specific research questions to be answered in the study are:

1. Can the prevalence of malnutrition in women, lactating mothers and children aged 6-23 months be reduced by linking agriculture to nutrition?
2. Will the nutritional status of farm families (especially women, lactating mothers and children) exposed to agriculture linked to nutrition differ significantly from those linked agriculture only?
3. Is focused BCC combined with nutrition-sensitive agriculture interventions to improve feeding practices more effective than only agricultural intervention in reducing malnutrition among children, pregnant and nursing mothers?
4. Will focus group discussions and visioning exercises with women and men interested in the subject improve household nutrition?

#### Objectives:

1. Summarize the results of the baseline nutrition survey and publish it as a booklet
2. Draft and submit at least on paper to an international peer reviewed journal from the baseline nutrition survey
3. Identify and empower women's Interest Groups (WIG) in the intervention communities to grow vegetables and legumes and keep livestock to improve household dietary diversity
4. Improve infant and young child feeding (IYCF) practices through the development and piloting of an innovative program that will stimulate behavior change towards feeding children with diversified foods
5. Assess the effect of promoting the preparation and utilization of available local foods as appropriate complementary foods for children on the nutritional status of children 6-36 months
6. Establish the quantity and quality of foods consumed by women of childbearing age and children under five in selected target communities
7. Determine the effect of soil type and fertilizer use on processing, nutritional and anti-nutritional characteristics of maize, soybean and cowpea varieties
8. Conduct studies on the effect of traditional processing methods on nutrient retention and bioavailability
9. Conduct awareness campaigns on nutrition issues for the target population and communities
10. Conduct trainings on Essential Nutrition Actions to improve household nutrition and health of the target groups
11. Develop and refine training modules on existing materials to improve farm household nutrition.
12. Link nutrition knowledge and practices to dietary and crop/tree diversity and farm productivity
13. Monitor behavior change related to child feeding
14. Evaluate milk processing methods to increase storage quality and shelf-life

## 6. Work-plan and procedures

<b>Activity 1</b>	Expert workshop to agree on integrated activities in Ghana	
Lead Scientists(s)	Asamoah Larbi	Institution(s): IITA
Other Scientist(s)	Mahma Saaka, Amau Abdul-Kahad, Sofo Mutaru, Roland Kanlisi	
Location(s)	Bolga, Tamale	

#### Procedures

An expert workshop will be organized in May 2014 to discuss possibilities of linking the agricultural activities with nutrition and health. Key activities will be identified. A committee will be set up to oversee the implementation of the planned activities in selected intervention communities. Possibilities of inviting leaders of the Africa RISING nutrition activities in Mali will be explored.

<b>Activity 2</b>	Publish results of the nutrition baseline survey in Ghana	
Lead Scientists(s)	Mahama Saaka, Mary Glover	Institution: UDS, FRI
Partner(s)	Asamoah Larbi, Amau Abdul-Kahad, Sofo Mutaru	
Consultant(s)	To be decided	
Location(s)	Tibali, Duko, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

*Sub-activity 2.1: Publish a booklet from the nutritional surveys:* Two baseline nutrition surveys were conducted in the Africa RISING intervention communities by UDS and FRI in 2013. Data were analyzed and draft reports prepared. A consultant will be hired to summarize the two reports into an easy to read



booklet(s). Data will be summarized and formatted for publication in international peer reviewed journals.

*Sub-activity 2.2: Draft and submit papers for publication in peer reviewed journals:* Data from the two surveys will be reviewed and re-analyzed if need be. At least two papers will be drafted by each Institution and submitted for publication in peer reviewed journals.

<b>Activity 3</b>	Improve nutritional knowledge of women in Ghana	
Lead scientists(s)	Mahama Saaka	Institution: UDS
Other scientist(s)	Jacob Mahama, Sofo Mutaru	
Location(s)	Tibali, Duku, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

Community and health and nutrition workers, and members of women's groups in the intervention community be trained in focused BCC in nutrition and health. This will equip health service providers with the technical, oriented nutrition knowledge and counseling skills needed to support pregnant women, breast-feeding mothers, children under two years of age, and other key family members to adopt optimal nutrition practices.

<b>Activity 4.</b>	Evaluate strategies for improving household nutritional diversity in Ghana	
Lead Scientists(s)	Mahama Saak	Institution: UDS
Other scientist(s)	Asamoah Larbi, Jacob Mahama, Sofo Mutaru	
Location (s)	Tibali, Duku, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

#### Procedures

A 400-600 households with women and nursing mothers with children aged 6-36 months will be randomly selected from the 25 intervention communities. At least 50 households will be randomly assigned to one of the following treatments:

1. Behavior change communication training every month (BCC).
2. Growing legumes (cowpea, soybean, groundnut), vegetables and rearing livestock (sheep, goats, poultry and pig).
3. BCC + Legumes, Vegetables and Livestock

The BCC training will be offered by community and health and nutrition workers, and members of the women's groups in the intervention communities who have been trained BCC in nutrition and health. This will equip the women, lactating mothers with children below 5 years and pregnant women, to adopt proper health care and nutritional practices. Community-based growth and monitoring promotion (CBGMP) will be established in the participating communities for bio-monthly weighing of children under 5 year. Surveys will be conducted to document diet diversity and farmer perception

A cluster non-randomized controlled trial will be used to collect quantitative primary data from mother/child pairs. This means a controlled pre-test/post-test design involving two cross-sectional surveys at baseline and end point follow-up will be used to determine the outcome/impact of the program. This will involve making observations before and after the implementation of an intervention, both in the communities that receive the intervention and in comparison communities.

Comparison of selected indicators at baseline and at end of project will give an indication of changes that have taken place with time. Additionally, a comparison between intervention and control communities will show the changes which can be attributed to the program interventions. A combination of use of control group and baseline data will strengthen the validity of the effect size. Comparisons will thus be made between communities and over time. The same clusters used in the baseline will be used in the end-line evaluation.

<b>Activity 5</b>	Add value to crop and livestock products to improve household income and nutrition in Ghana	
Lead scientists(s)	Francis Appiah	Institution: KNUST
Other scientist(s)	Alhaji Mahama	
Student (s)	Martha Agyiri	
Location(s)	Tibali, Duku, Botingli, Tibognayili, Cheyohi, Samboligo, Bonia, Nangua, Zanko, Guo, Passe, Goli, Nato-Douri	

## Procedures

*Sub-activity 5.1: Community-based milk processing and marketing:* Workshop will be held for men and women to document local milk processing practices, and identify needs and constraints. Identify suitable technologies to improve the collection and processing of milk at the household level, improve hygiene and lower labor requirements.

*Sub-activity 5.2: Milk processing:* Test at the household level alternative methods of processing milk, monitor milk and milk products for contamination during collection, processing, handling, transporting and marketing and for chemical composition. Subject to a feasibility study, establish a low cost, household-based milk processing unit to serve the community. Women will be trained in improved methods of milk processing. Traditional versus improved methods of processing milk to cheese and butter will be compared using 15 -20 household for each method. Equip the unit to pasteurize milk, remove the fat and press the cheese.

*Sub-activity 5.3: Establish community-based milk collection:* Small-scale dairy farmers will be encouraged to form interest groups. The project will link the groups to milk companies to establish milk collection centers to sell their milk. Community-based milk collection and processing units with the support of a credit scheme will be established. This activity is conditional on there being sufficient demand for milk products and on securing additional funding.

*Sub-activity 5.4: Develop and test new food products/blends from major crops and livestock:* This sub-activity will form part of an MSc dissertation research. Different breakfast meals and infant formulae will be tested. This includes millet based (Hausa koko flour) and Fula (Soyamilk/groundnuts). Experiment 1 will compare solar and sun drying effects on the following treatments/levels of substitution: 1. 100% millet, 2) 95% millet + 5% groundnut, 3) 90% millet + 10% groundnut, 4) 85% millet + 15% groundnut and 5) 80% millet + 20% groundnut. Treatments for Experiment 2 are: 1. 100% fulla, 2) 95% fulla + 5% soya milk (SM), 3) 90% fulla + 10% SM, 4) 85% fulla + 15% SM and 5) 80% fulla + 20% SM. Data to be collected include: sensory evaluation, consumer acceptance, proximate composition (mineral, vitamins), shelf live studies, storage pest, microbiological quality and packaging.

<b>Activity 6</b>	Review and document nutrition activities in Mali	
Lead Scientists(s)	Anehmbom Mundi	Institution: ICRAF
Other Scientist(s)	Eva Weltzien	
Consultant(s)	To be identified from IRSAT-DTA	
Location(s)	Koutiala district, Sirakele and M'pessoba villages	

## Procedures

*Sub-activity 5.1: Review and confirm nutrition training modules with input from nutritionists:* Prioritize the modules for revision by the project team. Focus group meetings for feedback on methods, themes, and topics, training periods. Joint group meetings to elaborate modules. Final revision to be verified with nutritionists and communication specialist. Compiling of prioritized modules in forms appropriate for use by partners, community based organizations and others for up scaling.

*Sub-activity 5.2: Participatory evaluation of the nutrition field schools:* The evaluation of learning outcomes at the trainer level, and participants in NFS villages. Assess the previous practices used and determine the training methods and approaches that were productive. Use productive methods to develop nutrition training guides.

*Sub-activity 5.3: Joint Ghana-Mali nutrition planning to develop 2015 work plans:* Identify the nutrition goals for the region, as determined by health officials. Determine how to best meet those objectives, with skills and resources, review methods used in Ghana, develop methodology for Mali.

## 7. Activity schedule

Activity	2014				2015				2016			
	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>	Q <sub>4</sub>
1. Organize expert workshop	x	x										
2. Publish results of baseline survey	x	x	x									
3. Enhance nutritional knowledge	x	x	x	x								
4. Evaluate dietary diversity strategies	x	x	x	x	x	x	x	x				

5.1 Review training modules	x	x	x
5.2. Evaluate nutrition field schools		x	x
5.3. Ghana-Mali joint planning			x x

## 8. Capacity building

	<i>Male</i>			<i>Female</i>		
	2014	2015	2016	2014	2015	2016
Farmers	50	100	150	300	400	500
Farmers' associations				10	10	15
Extension officers				3	7	8
Researchers				2	5	10
Input dealers				0	0	0
Policy makers				0	2	5
Development partners				3	5	5

## 9. Student training

	<i>Male</i>			<i>Female</i>		
	2014	2015	2016	2014	2015	2016
BSc	3	5	5	2	3	3
MSc students	1	2	2	1	2	2
PhD students	0	0	0	0	0	0
Interns/non-degree	5	10	10	5	7	6

## 10. Communication and dissemination

	2014	2015	2016
Workshops/meetings	2	2	
Field days		1	
Conference papers	1	1	1
Journal article	2		

**11. How are gender issues addressed?** Pregnant and lactating women and children below 23 months are targeted.

## 12. Deliverables

- 1 Workshop report outlining agriculture-nutrition related activities to improve dietary diversity
- 2 A booklet on household nutrition
- 3 At least two papers drafted and submitted by June 2014
- 4 At least 50 community health and nutrition staff trained in BCC
- 5 At least 100 households involved in agriculture-nutrition-health trials by August 2014.
- 6 Revised nutrition training modules-Mali
- 7 Nutrition training guidelines-Mali

## 13. Expected outputs

- Results of the baseline nutrition survey published
- Integrated agriculture-nutrition-health activities identified
- Capacity of women strengthened for implementation of integrated agriculture-nutrition-health
- Nutritional status of farm-families improved through linking agriculture, nutrition, and health
- Effective methods of nutritional training and communication
- Women understand nutritional benefits of locally available food resources and use them in diversified diets

## 14. Expected outcomes

- Household adopt behaviors that will improve dietary diversity
- Women apply their nutritional skills in food preparation
- Households apply post-harvest technologies that increase shelf-life of their milk products

### 15. Potential impact of outcome

The maternal and child nutrition will be enhanced through access to high quality and diverse diets, better cooking methods and thus improved food and nutrient intake resulting in an improvement in food security and health of the target groups (about 10% in the short term and by about 20% in the long term).

<i>Item</i>	<i>Impact</i>
Household crop and livestock production	Crop and livestock production by women and women's groups will be intensified and outputs increased
Household income	Incomes will increase through sale of excess crop and livestock outputs and income diversification
Household nutrition (women and children)	Dietary diversity will increase and mal-nutrition in children below 23 month declined

### 16. 2014 Budget (US\$)

	Budget Line	UDS	IITA	ICRISAT	ICRAF	AVRDC	AMEDD
Activity 1	Personnel	0	1000				
	Services	0	4000				
	Supplies	0	1000				
	Travel	0	2000				
	<b>Total</b>	<b>0</b>	<b>8000</b>				
Activity 2	Personnel	2000	2000				
	Services	1000	5000				
	Supplies	1000	2000				
	Travel	0	1000				
	<b>Total</b>	<b>4000</b>	<b>10000</b>				
Activity 3	Personnel	3000	0				
	Services	14000	0				
	Supplies	1000	0				
	Travel	2000	0				
	<b>Total</b>	<b>20000</b>	<b>0</b>				
Activity 4	Personnel	3000	3000				
	Services	1000	3000				
	Supplies	1000	10000				
	Travel	1000	5000				
	<b>Total</b>	<b>6000</b>	<b>21000</b>				
Activity 5	Personnel	0	3000				
	Services	0	3000				
	Supplies	0	7000				
	Travel	0	3000				
	<b>Total</b>	<b>0</b>	<b>16000</b>				
Activity 6	Personnel	0	0	11000	8000	4000	4000
	Services	0	0	3000	6000	1000	4000
	Supplies	0	0	3000	3000	1000	2000
	Travel	0	0	9000	4000	1000	2000
	<b>Total</b>	<b>0</b>	<b>0</b>	<b>26000</b>	<b>21000</b>	<b>7000</b>	<b>12000</b>
<b>Grand Total</b>		<b>30000</b>	<b>55000</b>	<b>26000</b>	<b>21000</b>	<b>7000</b>	<b>12000</b>

### 3. Consolidated budget for WA 2014

#### 2014 Consolidated Budget (US\$)

Country	Institute	Budget (US\$)
Ghana	IITA	737000
	ILRI	150000
	AVRDC	61000
	IWMI	100000
	CIAT	100000
	SARI	52000
	UDS	50000
	KNUST	20000
	<b>Total</b>	<b>1270000</b>
Mali		
	ICRISAT	187000
	ICRAF	125500
	AVRDC	106000
	MOBIOM	37000
	AMEDD	48500
	IER	55500
	AMASSA	26000
	WUR	5000
	ILRI	110000
	<b>Total</b>	<b>700500</b>